

*The New Method of Fortification
as practiced by Monsieur
VAUBAN Engineer general of France*



London Printed
For A. Dellsworth, S. Ballard, and J. Batley.

1722

*The New Method of Fortification
as practiced by Monsieur
VAUBAN Engineer general of France*



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1737

THE NEW
METHOD
OF
FORTIFICATION,

As practised by Monsieur *de VAUBAN*,
Engineer-General of *FRANCE*.

Together with a new Treatise of GEOMETRY.

The FIFTH EDITION,
Carefully revised and corrected by the Original.

To which is now added,
A Treatise of MILITARY ORDERS, and the
ART OF GUNNERY, or throwing of
BOMBS, BALLS, &c. to hit any Object
assigned.

The whole Work illustrated with thirty-two Copper Plates.

L O N D O N:

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THE NEW

METHOD



FOR THE

A new and improved method of teaching
the principles of the English language

Together with a new system of grammar

THE METHOD

OF TEACHING THE ENGLISH LANGUAGE

BY
J. W. D. O. R.
OF THE
UNIVERSITY OF
CAMBRIDGE

THE METHOD OF TEACHING THE ENGLISH LANGUAGE

J. W. D. O. R.

THE METHOD OF TEACHING THE ENGLISH LANGUAGE

J. W. D. O. R.

TO HIS
G R A C E
THE
DUKE of ORMONDE.

May it please your GRACE,

THE general Complaint of the want of Books of *Fortification* in our *English* Tongue, has encouraged me to translate that of Monsieur *Vauban* : To which I was invited by the almost universal Applause it has received from the most competent Judges. Nothing could have emboldened me to the Presumption of this Address, but the Good and Welfare of my native Country, by proposing your Grace to the Imitation of our Nobility and Gentry, which seems to be the only Means for this Kingdom to recover its ancient

A 2 Glory.

The Epistle Dedicatory.

Glory. I doubt not, but that brave Example which your Grace continually sets to the whole Nation, will inspire the Men of Quality to come up to it, as near as possible : Which, if they had always done, *Vauban* might, without any great Detriment to us, have been confined to the Territories of his Master. That your Grace may ever prosper, and receive the Honours due to so great Merits ; as it is the greatest Good can be wished you, so it is no less the unfeigned Desire of,

May it please your GRACE,

Your GRACE's most obedient,

and most humble Servant,

A. S.

T H E

THE
P R E F A C E.

THIS little Tract, which was chiefly designed by the ingenious Author, for the Use and Benefit of young Gentlemen and others, addicted to the Study of this Part of the *Mathematicks*, who have not Leisure or Opportunity to read over the vast Systems of voluminous Writers, has deservedly obtained so great a Repute among the Curious, that it is translated into several Languages; and the Acceptance it has met with, has already sold off three Impressions in our own. It contains an exact and sufficient Explication of all the Terms that are necessary to the Subject; and, in general, all that is requisite for the Theory and Practice of a good *Soldier*, down from a General to a private Centinel. You have therein exhibited the true Mensuration of *Heights, Lengths, Planes, Solids, and Concaves*; as also the Science called, *The Transmutation of Bodies*; which is the Subject of the First Part. In the Second are explained

The P R E F A C E.

the Rules that are observed by the *French* Engineers at this Day, in raising their Works ; and, at the same Time, are produced the different Sentiments of the *French* among themselves, as to this Matter ; it is likewise shewn wherein their Manner of Operation differs from that of the *Germans*, and other Nations. Lastly, The most clear and accurate Method of *Fortification* is plainly taught.

The Word *Geometry* is derived from the *Greek*, $\gamma\eta$ and $\mu\epsilon\tau\rho\epsilon\iota\nu$; importing, *to measure the Earth* ; so that *Geometry* (with respect to its Etymology) is only the Art of measuring Land ; yet in a larger, and more proper Sense, it is applied to all sorts of Dimensions. As for the Original of this Science, it is indeed very uncertain ; and it is believed by many, that the *Ægyptians* were the first Inventers thereof : For in regard that the River *Nile* does every Year overflow the Country of *Ægypt* ; those Inundations which generally overthrew, and confounded all the Land-Marks, obliged the Inhabitants to invent certain Measures, by the Means whereof, they might be able to distinguish, and adjust the Limits of their respective Grounds from those of their Neighbours, when the Waters were withdrawn. And this Opinion is not altogether to be rejected : Especially if we consider that *Moses* is generally reputed to have learned this Art, among others of them, during his Residence in the *Ægyptian* Court. However, since there were not very many Men who applied themselves to the Study of
good

The P R E F A C E.

good Literature in those early Ages of the World; the *Mathematicks*, and *Geometry* in particular, were, as it were, locked up within the Breasts of some few learned and skilful Artists, until the Time of *Thales*, who first publicly professed them in *Greece*; nevertheless the *Grecians* were not very diligent in promoting and improving these noble Sciences, and only taught them privately; neither was there any one that undertook to shew the Usefulness and Necessity of this kind of Learning, until *Euclid* wrote his *Elements*; which gave Occasion to the publishing of a great Number of excellent Treatises on the Subjects, that are now extant.

To this Treatise you have annexed another of *military Orders*, and the *Art of Gunnery*. So that taking the Whole together, I am apt to think, there will be scarce found a Book so universal of the Kind, and so necessary in the first Place to all military Persons, of what Order or Rank soever; and in the next, to all Gentlemen that are willing to understand what they may meet with, not only in reading of modern Histories, but very probably in most of the Gazettes of the approaching Summer. However we are willing to submit the Whole to the impartial Censure of the candid Reader.

An Advertisement to the *Book-Binder.*

1. **C**A R E must be taken not to cut the blank Paper on which the Plates are wrought off; by reason that the Figures must be so placed as to fold out of the Book.

2. There are eight Figures which must be placed at the End of the Treatise of *Geometry*, and are marked thus: *Geom. Pl. 1, 2, 3, 4, 5, 6, 7, 8.*

3. The other Figures belong to the *Fortification*, and *Gunnery*, and are to be placed at the End of the Book, and set in order as they are marked; A, B, C, D, E, F, G, H, I, K, L, M, N, O, P, Q, R, S, T, V, W, X, Y.



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A NEW

A NEW
TREATISE
OF
GEOMETRY.

BOOK I.

CHAP. I.

AS an Introduction to our Subject, at our first Entry, we shall begin with the Definition of *Geometry*, and the Explication of those Terms that are hereafter to be made use of.

Geometry is a Science which treats of *Magnitudes*, and it is the principal Part of the *Mathematicks*.

1. *Magnitude* is a continued Quantity, which consists either in *Lines* or *Angles*, in *Surfaces* or *Bodies*.

2. A *Line* is a Length without Breadth, whose Extremities are called *Points*.

B

3. A

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3. A *Point* is something which cannot be divided.

4. A *Line* is right, crooked, or mixed: A right Line is that which goes without Turnings from one Point to another. A crooked Line is that which goes off from a right Line, by one or more Turnings: And a mixed Line is that which is Part right and Part crooked.

5. A *Surface* is Length with Breadth; whose Bounds are called *Lines*.

6. These Lines are either parallel or oblique. Parallel Lines are those which are every where equally distant from each other. Oblique Lines are those which meeting at a Point make an Angle.

7. It is called a right Angle when one of the Lines is perpendicular to the other. It is called an oblique Angle when one of the Lines is not perpendicular to the other. It is called a right-lined Angle when it is made up of two right Lines. It is called a Curve-lined Angle when it is made up of two crooked Lines. It is called a mixed Angle when one of the Lines is right, and the other curve. It is called an acute Angle when it is less than a right one. And it is called an obtuse Angle when it is greater than a right Angle.

8. A *Figure* is a Magnitude bounded by one or more Lines and Surfaces, whereof some are plain, some solid.

9. A *Circle* is a plain Figure bounded by a Circumference, the middle Point whereof is called the Center, from which all right Lines drawn to the Circumference are equal.

10. A *Diameter* is a right Line, which goes through the Center, and touches the Circumference in two Points.

11. A



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11. A *Semi-Circle* is the half of an Entire Circle.

12. An *Oval* is a plain Figure bounded by its own Circumference, within which no Point can be taken from which all right Lines drawn to the Circumference can be equal.

13. A *Triangle* may be considered either with respect to its Sides, or its Angles: In respect to its Sides, it is either an *Equilateral*, which has three equal Sides: Or an *Isosceles*, which has two Sides only equal; whose third is called the *Base*: Or a *Scalene*, which has three unequal Sides: In respect of its Angles, it is either right-angled, which has one right Angle: Or acute-angled, which has three acute Angles: Or obtuse-angled, which has one obtuse and two acute Angles. One of the Lines in a right-angled Triangle is called the *Base*: The second the *Perpendicular*: And the third the *Hypothenusal*.

14. A *Quadrilateral* Figure is that which has four Sides and four Angles: And it is either *Equilateral*, which has four equal Sides, or *Inequilateral*, whose Sides are unequal.

15. An *Equilateral Quadrilateral* Figure has either right Angles as a *Square*, or oblique Angles as a *Rhombus*.

16. An *Inequilateral Quadrilateral* Figure is either a *Rect-angle* or *Right-angled Parallelogram*, which has its opposite Sides parallel and consequently equal, and its Angles right, or a *Rhomboides* which has its opposite Sides equal and parallel; all other *Quadrilateral* Figures are called *Trapeziums*.

17. A *Tetraëdron* is a solid Figure, or a Body which is bounded by four equal Triangles.

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18. A *Pyramid* is a Body bounded by several Triangles, which making one Surface for a Base, meet all in one Point.

19. A *Prism* is a Body which has two Bases, equal and parallel each to other.

20. A *Parallelepiped* is a Body bounded by six Parallelograms, whereof the two opposite ones are always equal and parallel.

21. A solid *Trapezium*, or Trapezoidal solid is a Body bounded by plain Surfaces, which form neither a Prism, nor a Parallelepiped.

22. A *Cone* is a Body made by the turning of a right-angled Triangle round a Circle, the angular Point of the right Angle being fixed in the Center.

23. A *Cylinder* is a Body made by the turning of a right-angled Parallelogram round one of its Sides, till it end where it began.

24. A *Cube* is a Body bounded by six equal Squares.

25. An *Octaëdron* is a Body bounded by eight equal and equilateral Triangles.

26. A *Dodecaëdron* is a Body bounded by twelve equal and equilateral Pentagons.

27. An *Icosaëdron* is a Body bounded by twenty equal and equilateral Triangles.

28. A *Triangular Prism* is a Body bounded by three right-angled Parallelograms, having two Triangles for its Bases.

29. A solid *Rhomb* is a Body bounded by six equilateral oblique-angled Squares.

30. A solid *Rhomboid* is a Body bounded by four oblique-angled Parallelograms, having two oblique-angled equilateral Squares for their Bases.

C H A P. II.

To know how Figures are made, the following Problems must be examined.

P R O B L E M S.

I. To draw a Line parallel to a give Line.

MARK upon the given Line any two Points A B where you please, and from them as Centers at an equal Distance draw two Arches E F, in drawing a right Line by E F you have your Parallel.

II. From the Point G, to draw a Parallel to a given Line H I.

1. Draw an Arch from the Point G, which touches the given Line only in K.
2. With the Distance G K, draw another Arch upon the given Line M N.
3. The Line drawn by G N shall be parallel to the given Line H I.

III. To raise a Perpendicular on a given Line, from a given Point.

1. Take a Distance from the given Point (what you please) to the right, as A B.
2. Take the same Distance to the left, as A C.
3. Take B C and draw two Arches which intersect each other at D.

B 3

4. Join

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4. Join D and A together, and you will have your Perpendicular.

IV. To raise a Perpendicular at the End of a given Line AB.

1. Draw a Circle to the Point B, from the Center C, which may be taken at Pleasure.

2. From the Point D, where the Circle cuts the given Line, draw a right Line through the Center C, till it touches the Circle on the other Side, as at E.

3. Join E and B together, and you will have your Perpendicular.

V. From a given Point G, to let fall a Perpendicular upon a given Line.

1. Draw an Arch from the Point G, which may cut the given Line in two Places, as C D.

2. From C D draw two Arches under the Line which shall intersect each other at E.

3. Join E and G together, and you will have your Perpendicular G F.

VI. To divide a given Line into two equal Parts.

1. From the Points A B draw two Arches which shall intersect above the given Line at C, and below it at D.

2. Join C and D together, and you shall have your Line cut into two equal Parts.

VIII. To

VII. To divide a Line AB into several equal Parts.

1. Draw CD a Line at Pleasure, and mark as many Parts as the given Line AB ought to have; fix for Example, upon this Line as CE.
2. Take CE and draw two Arches which may intersect in F.
3. Draw all these six Parts in F.
4. Take the given Line AB, and lay it upon the Lines FE and FC, as GH.
5. Join GH together, you will have your given Line AB divided into six equal Parts.

VIII. To describe an Angle equal to an Angle given.

1. Let the given Angle be BAC.
2. Draw the Arch ADE.
3. Draw a Line IL, and upon this Line an Arch with the Distance AD, as FG.
4. Set the Distance DE upon the Arch FG, as FH.
5. Draw a right Line from the Point I to the Point H, which will make an Angle equal to the given Angle.

IX. To divide an Angle into two equal Parts.

1. Let the given Angle be BAC, draw the Arch ADE.
2. From the Points DE draw two Arches which shall intersect each other at F.
3. The Line drawn from F to A will cut the Angle into two equal Parts.

X. *To draw a Circle through three given Points ABC, or to find the Center of a given Circle, or to finish a Circle when there is but one Part given.*

1. With the Points A B, make two Arches which shall intersect at D above, and at E below the given Points.

2. Draw a right Line from the Point D to G.

3. Do the same Thing with B C, so that they may intersect in F G.

4. Draw another right Line from F to G, and there where this Line intersects the first, as for instance at G, you will find the Center, by which you may draw the Circle through the three given Points.

XI. *To make a Circle two, three, or four Times bigger than the given one, &c.*

1. Divide the given Circle into four equal Parts A B C D, with the Center marked at E.

2. Take the Distance A B and put it from E upon the Perpendicular, as E F, and with this Distance draw a Circle, as big again as that given.

3. To make a Circle twice as big, take A F, and put it from E upon the first Perpendicular, as E G, and the Distance E G will be the Semi-diameter of the demanded Circle.

4. To make a Circle thrice as big, put the Distance A G upon the same Perpendicular, as E H, and the Distance E H will be the Semi-diameter of the demanded Circle. Thus you may enlarge a Circle for ever.

XII. *To*

XII. To make an Oval.

1. Draw a Line, and thereupon the Circle B A C.
2. From C draw another Circle through B, as C B D.
3. Take Care that these two Circles intersect each other, as in E F.
4. From the Point of Intersection E, draw right Lines through B C, which shall cut the two Circles in G H.
5. From the Point E, draw an Arch from G to the Point H.
6. Keep this Distance, and do the same Thing from the other Point of Intersection F, as I K, and so your Oval will be compleat.

XIII. To draw a Spiral Line.

1. Upon a straight Line, draw the Arch A B C.
2. Take B C, and fixing one Point of the Compass upon B, draw from the Point C another Arch, which shall touch the same Line in D.
3. Take the first Center A, and draw another Arch from D, that shall cut the Line in E.
4. Return to the Point B, and from it as a Center draw from E another Arch to F.
5. Take A as a Center, and draw an Arch from F to G; and so on for ever.

XIV. To divide a Circle into 360 equal Parts.

1. Divide a Circle into four equal Parts, as A B C D, whose Center is E.
2. From

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2. From A through E draw the Arch FG; so also draw from B the Arch IH, and from C draw the third KL; and at last from D draw the last Arch MN.

3. Having by these Articles divided the Circle into twelve equal Parts, afterwards divide every one of these twelve into three other equal Parts, and then you will have thirty-six equal Parts.

4. Divide afterwards every one of these thirty-six into ten equal Parts, and your Circle will be divided into three hundred and sixty equal Parts.

XV. To make an Equilateral Triangle.

Take a given Line AB, and from those two Points draw two Arches which shall intersect at C; from C draw two right Lines to A and B; these will make an Equilateral Triangle.

XVI. To make a Triangle equal to a given one.

1. Let the given Triangle be ABC, draw a Line at Pleasure, and mark thereupon the Length AB, as DE.

2. Take the Distance BC, and from the Point E draw an Arch.

3. Take the Distance AC, and from D draw another Arch which shall intersect the first at F.

4. Join AE and FD together, you will have a Triangle equal to the given one ABC.

XVII. To divide a Triangle into several equal Parts.

1. Let ABC be the Triangle to be divided into five other Triangles: First divide the longest Side

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Side BC into five equal Parts, so that the fifth Part, marked at D , may be joined to A .

2. Divide the longest of the two other Sides into four equal Parts, and let one of them marked G be joined to D .

3. Divide the remaining Part DC into three equal Parts, and join that marked F by a right Line to G .

4. Divide the Remainder GC into two equal Parts, and join that marked E by a right Line with F . So you may have five equal Triangles, viz. ABD , ADG , GDF , GFE , and EFC .

XVIII. To make a Square.

1. Take the Line AB , and raise a Perpendicular upon B , of the same Height as BC .

2. With the same Distance make two Arches from A and C which shall intersect at D .

3. Join DA , and DC by right Lines: And you will have a Square.

XIX. To make a Parallelogram.

1. Draw a long Line AB , and upon B raise a small Perpendicular BC .

2. Take the Distance BC , and by the Point A draw an Arch.

3. Once more take the Line AB , and by the Point C make an Arch which shall intersect the other at E ; join E to A and C , and you will have this Parallelogram.

XX. To

XX. To draw a Pentagon of equal Angles without a Circle.

1. Draw a long Line AB , and mark upon it the Distance AC .
2. Raise a Perpendicular upon C , equal to AC , as CD .
3. Divide the Line AC into two equal Parts, as AE , EC .
4. Set the Point of the Compass upon E ; and with the other Point draw an Arch from D , which shall touch the given Line at F .
5. By the Points AC , and the Distance AF , draw two Arches intersecting at G .
6. Take only the Distance AC , and by the Points GA , draw two Arches intersecting each other in I ; So likewise by the Points GC , draw two other Arches which shall intersect each other in K .
7. Join AI , IG , GK , and KC together by right Lines, and you have your Pentagon.

XXI. To make a right-lined Triangle equal to a Circle given.

1. Divide the Diameter of AB the given Circle into seven equal Parts.
2. Raise a Perpendicular upon B three Times as long as the Diameter AB , and a seventh Part over, as BC .
3. Draw a right Line from C to D the Center of the given Circle, and that gives you the Triangle.

XX. To

XXII. *To find the Circumference of a Circle, having only the Diameter.*

This Problem must be wrought after the same Manner as the foregoing one.

XXIII. *To make a Square equal to a given Circle.*

1. Divide the Diameter AB into seven equal Parts.
2. Double this Diameter, and add a seventh Part of itself to it, as AC .
3. Divide the first Diameter AB into two equal Parts, as AD .
4. Divide the Line DC into two equal Parts, and taking the middle Point E , draw from D to C an Arch, as DFC .
5. Raise a Perpendicular upon E to touch the Circle in F : This Line EF shall be a Side of the required Square: The rest is wrought by the eighteenth Problem.

XXIV. *To make one Square equal to two.*

1. Let one of the given Squares be $ABCD$, and the other $EFGH$.
2. Join them both, so that the Sides BC , FE , may make one right Line CBE .
3. Join A to E , and raise a Perpendicular upon E of the same Length, as AE .
4. Keep the same Length, and from the Points K A , make two Arches to intersect in I .
5. Join KI , and IA , and your Square will be made.

XXV. *To*

XXV. To make a Square equal to a Parallelogram.

Let the given Parallelogram be $ABCD$.

1. Lengthen the Base DC , and add to it the other Side of the Parallelogram BC , as CE .
2. Divide the Distance DE into two equal Parts, and from the middle Point F draw a Semi-circle, from D towards E .
3. Raise a Perpendicular upon C to touch the Semi-circle in G ; this will be a Side of the required Square; set it upon the first lengthened Line, and you will have another Side, as CI .
4. Keep the same Distance, and from the Points G I , make two Arches to intersect in H ; join GH , and HI together, and your Square will be made.

XXVI. To make a Square two, three, or four Times greater than it is.

Let the given Square be $ABCD$.

1. Lengthen the Side AB , and take the Distance BD , and set it upon the lengthened Side AB , as AE , and it will be a Side of a Square double to that given at first.
2. Afterwards observe what was said above in the eleventh Problem.

XXVII. To make an Equilateral right-angled Square equal to an oblique-angled Parallelogram $ABCD$.

1. From the Points A B let fall Perpendiculars to the lower Line, as AE , and join it afterwards to the Perpendicular B , as BF .

2. And

2. And when you have the right-angled Parallelogram $AEBF$, work on by the twenty-fifth Problem.

XXVIII. *To make a right-angled Square equal to the Rhomb $ABCD$.*

1. From the Points B C , let fall Perpendiculars upon the Line, and set the Distance BE , upon the other Point C , as CF .

2. Join EF together, and the Sides BCE EF will make a right-angled Square equal to a given Rhomb.

XXIX. *To make an Equilateral right-angled Square equal to the Triangle ABC .*

1. Lengthen the Base CB , and divide the same Base into two equal Parts, as CD , DB .

2. From the Point B let fall a Perpendicular equal to BD , as BF .

3. Lengthen BF upwards, and from the Point A draw a Parallel to the Base CB , which shall cut the lengthened Line BF in E .

4. Divide the Distance FE into two equal Parts, and from G the middle Point draw an Arch from E to F ; and from the Point H , where this Arch touches the first lengthened Line CB , to B shall be the first Side of the Square, which laid upon the Line BE , will give another Side BI ; afterwards from the Points I H , make two Arches which shall intersect each other in K ; and join HK and KI together, and your Square will be made.

XXX. *To*

XXX. *To make a Parallelogram equal to a given Triangle ABC .*

1. Divide the Base AB into two equal Parts, as AD , DB .
2. Divide the Side CB into two equal Parts, as BE , EC .
3. Draw a right Line from D to E , what Length you please, and take the Distance DE , and set it from the Point E , to lengthen it, as EF .
4. Take DF , and from the Point B make an Arch.
5. Take DB , and from F intersect this Arch in G .
6. Join FG and GB together, and your Parallelogram will be made.

XXXI. *To make a Parallelogram equal to a right-angled Square $ABCD$.*

1. Lengthen the Side of the Square AB , adding double its own Length to it, as BF .
2. Divide the Side of the Square BC into two equal Parts, as BE , EC .
3. Take BF , and from the Point E make an Arch.
4. Take BE and intersect this Arch from the Point F in G .
5. Afterwards join EG and FG together, and you have the Parallelogram required.

XXXII. *To*

XXXII. *To make a right-lined Figure equal to a Figure given.*

Let the given Figure be $ABCDE$.

1. Take any one of the Points, which you please; A for instance.

2. From A make as many Triangles as there are opposite Angles in the Figures ABC , ACD , ADE .

3. Then take a Line at Pleasure, of the Length of AB , as FG .

4. From the Point G , with the Distance BC , make an Arch.

5. With the Distance AC intersect this Arch from F in H , and join GH together.

6. From the Point H , with the Distance CD make another Arch, and intersect it from F in I , with the Distance AD , and this must be joined to H .

7. Take AE , and from this Point F make the last Arch; intersect it from I in K , with the Distance DE , and join it with IF : So the Figure $FGHIK$, will be equal to the given Figure.

CHAP. III.

Of BODIES.

PROBLEMS.

I. *To make an equilateral Tetraëdron.*

1. **M**AKE an equilateral Triangle ABC .
2. Place another equilateral Triangle

C
upon

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upon every Side, as ABE, BCD, and ACF, and your *Tetrahedron* is made.

H. *To make a Cube.*

1. Make an equilateral right-angled Square ABCD.

2. Upon every Side place another Square equal to the first, as ABEF, BCGH, DCIK, ADLM.

3. Join EF, GH, IK, and LM together by right Lines.

4. Place another Square equal to the rest upon one of these four, as KINO, and the *Cube* will be made.

III. *To make a Parallelepiped.*

1. Make a Parallelogram ABCD, and lengthen the Sides AC, BD, above and below.

2. Mark any Distance above AB you please, as AE, BF; and mark the same under CD as CG, DH, then join EF and GH together.

3. Above EF, mark the Distance AC, or BD, at I and K: And join IK together.

4. Lengthen EF and AB; upon the lengthened Lines mark the Distance AC, or BD, as FL, BM, EN, and AO.

5. Join L and MN, and O, together, and your *Parallelepiped* will be made.

IV. *To make a Cylinder.*

1. Make a long Square ABCD.

2. Divide AB into twenty-two equal Parts.

I

3. Upon

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3. Upon what Point you please raise a Perpendicular, of the Length of seven of these twenty-two Parts, as FG.

4. Upon the Line DC mark the Distance FB, as DH.

5. Let fall a Perpendicular from H of the Length of FG, as HI.

6. Divide FG and HI into two equal Parts: And from their middle Points draw Circles, and the Cylinder will be made.

V. To make a Cone.

1. From the Point A taken at Pleasure draw an Arch.

2. Divide it into twenty-two equal Parts; and join the Extremities GH, with A.

3. Let fall a Perpendicular where you please from the Arch, equal to seven of those Parts, as BC.

4. Divide BC into two equal Parts: From its middle Point, draw a Circle, which shall be a Base of a Cone made upon the Arch GH.

VI. To make a Triangular Prism.

1. Make a right-angled Parallelogram ABCD.

2. Divide AB and CD into three equal Parts, as AE, EF, FB, and CG, GH, HD.

3. Join EG and FH together by right Lines.

4. From E and F make two Arches to intersect in I, and join IE, and IF together.

5. Upon GH make an equilateral Triangle K, and your Prism will be made.

VII. *To make an Octaëdron.*

1. Upon one Line make three equilateral Triangles, as ABC , BDE , and EFG .
2. Lengthen the Line CG ; and mark upon the lengthened Line the Distance EG , as GH .
3. Join HF together, and with the same Distance from DF , make two Arches to intersect at K , and from CE , two others to intersect at I .
4. Join CI , and IE together, as also DK and FK , and the *Octaëdron* will be finished.

VIII. *To make a Dodecaëdron.*

1. Make a regular Pentagon $ABCDE$: The Center whereof may be F .
2. Take the Distance AF , and therewith from every Side draw two Arches mutually intersecting, as ABG , BCH , CDI , DEK and EAL .
3. From the Points $GHIKL$, with the Distance AB , describe five Circles, and divide each of them into five equal Parts; and you will have five other equal Pentagons about your first.
4. With the Distance HM or HN from M and N draw two Arches to intersect each other in O : From this Point, by the same Distance, draw another Circle through N and M , and divide it as you did the other into five equal Parts, and as $MNPQR$, and there join them all together.
5. Take the Distance ON , and from P and Q draw two Arches to intersect each other in S , which is a Center, from whence a Circle shall be drawn through PQ , which shall afterwards be divided

vided into five equal Parts, QP, PW, WU, UT, and TQ.

6. Repeat the same Operation upon TQ, TU, UW, and WP, and your *Dodecaëdron* will be finished.

IX. To make an Icosaëdron.

1. Make five equilateral Triangles upon the same Line, as ABC, BDE, DFG, FHI, and HKL.

2. From the Points AC make two Arches which shall intersect each other in M.

3. Join AM and ML together by right Lines.

4. Upon MC raise the equilateral Triangle N, upon CE, O; upon EC, P; upon GI, Q; and lastly upon IL, R.

5. Repeat the same Operation upon their Bases: For Instance, set the equilateral Triangle S upon AB; the Triangle T upon BD; the Triangle U upon DF; W upon FH; and at last the Triangle X upon HK: Which will finish the *Icosaëdron*.

X. To make a solid Rhomb.

1. Upon the same Line make four equilateral Triangles, GIM, IKN, KLO, LHP.

2. Join MP together by a right Line: As also GM, IN, KN, LO and HP.

3. Add to the Line NI its own Length beyond it, as IQ.

4. Add to the Line OK double its own Length, as KR, RF.

5. Join RI and FQ together.
6. Add to the Line IR its own Length beyond it, as RT : Do the same to NK , as KU : Then join UT together, and your solid *Rhomb* is made.

XI. To make a solid Rhomboid.

1. Make an equilateral Triangle ABC , and from BC another D .
2. Add to the Line CD twice its own Length, as DE , EF .
3. Add to DB its own Length, as DG .
4. Add to CB thrice its own Length, as BH , HI , IK .
5. With the Distance IB , from the Point G make an Arch.
6. Make another Arch with the Distance BG from I , which shall intersect the first at L , and join GL and LI by right Lines.
7. Add to GH thrice its own Length; HM , MO , and OP ; and join M and I together.
8. From K and M draw two Arches to intersect at N , and join KN , NM , MD , OE , and PF together: And the Rhomboid will be finished.

XII. To make a Polyëdron whose Base shall be a Pentagon.

1. Make a Square $ABCD$: And divide AB and CD into five equal Parts, as CE , BF , FG , GH , HD ; as also AI , IK , KL , LM , and MB .
2. Join EI , and FK , and GL , and HM , and DB , together.
3. Divide one Part of each of these Lines into twenty-two equal Parts: As FG , and KL .
4. Divide

4. Divide one of those twenty-two Parts into three other equal Parts.

5. Take eighteen of these twenty-two Parts, and $\frac{2}{3}$ of one more, as FN, and KO; and draw two Arches from KL, as also from FG, which shall intersect in P and Q: From P and Q as Centers draw two Circles, which being divided into five equal Parts by the Distances FG and KL, your Figure will be compleated.

CHAP. IV.

OF PYRAMIDS.

PROBLEMS.

I. *To make a Triangular Pyramid.*

1. FROM the Point A taken at Pleasure draw an Arch, which divide into three equal Parts, BC, CD and DE.

2. Join AB, AC, AD, and AE with right Lines; as also BC, CD, and DE, with other right Lines.

3. From the Points C D, with the Distance CD, draw two Arches to intersect in F.

4. Join CF and DF, and the *Pyramid* will be compleated.

II. *To make a Pyramid with an equilateral Square for its Base.*

1. From the Point A draw an Arch: Divide it into four equal Parts, BC, CD, DE, and EF,
C-4

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E.F, which are to be joined together by right Lines, as also A B, A F, A C, A D, and A E.

2. From the Point C, let fall a Perpendicular equal to C D, as C G.

3. With the Distance C G from G D, draw two Arches to intersect each other in H.

4. Join H G and D H together by right Lines, and you have the required *Pyramid*.

III. *To make a Pyramid whose Base is a Parallelogram.*

1. From the Point A draw a Circle, in which first mark a larger Arch, as B C; then a smaller one, as C D, then mark a third Arch (D E) equal to the first, and a fourth (E F) equal to the second.

2. Join A B, A C, A D, A E, A F, as also B C, C D, D E, E F, by right Lines.

3. From C let fall a Perpendicular equal to C D, as C G.

4. Take the Distance C G, and from B draw an Arch.

5. Take the Distance B C, and from G draw another Arch to intersect the first in H; join B H and H G together, and the Problem is finished.

IV. *To make a Pyramid with an equilateral Pentagon for its Base.*

1. Draw an Arch from A, which divide into five equal Parts, B C, C D, D E, E F, F G.

2. Join them all to A, and one to another, B to C, C to D, D to E, E to F, F to G, by right Lines.

3. Divide

3. Divide one of these five Parts, as DE, into twenty-two equal Parts, and one of them into three.

4. Take eighteen of the twenty-two Parts, and two of the three little Parts, and from the Points DE, make two Arches to intersect each other in H, which is the Center, from whence you are to draw a Circle big enough to be divided into five Parts, equal to the Distance DE. When you have this Pentagon for a Base, the Work is done.

V. To make a Pyramid, which shall have an Equilateral Hexagon for a Base.

1. Draw an Arch from A, and divide it into six equal Parts, BCDEFGI,

2. Join them to the Center A, as also B to C, C to D, D to E, E to F, F to G, G to I.

3. Take one of these six Parts (DE), and from D and E make two Arches to intersect in H.

4. From H draw a Circle big enough to be divided into six Parts equal to DE.

5. Having this Hexagon as a Base for the Pyramid, the Problem is wrought.

VI. To make a Pyramid with a Heptagon for its Base.

1. From A draw an Arch, and divide into seven equal Parts, BCDEFGH.

2. Join them to A, and also B to C, C to D, D to E, E to H, H to G, G to F, F to I, by right Lines.

3. Divide one of these Parts, FG for Instance, into seven equal Parts, and then one of these seven into eight more; then take eight of the larger Parts,

Parts, and the half Part of a little one, and with that Distance from the Points F G, make two Arches to intersect each other in K; for which as a Center draw a Circle through F G, which must be divided into seven Parts equal to F G, which when joined together, will serve for a Base of the Pyramid required.

VII. *To make a Pyramid with an Octagon for its Base.*

1. From A draw an Arch, divide it into eight equal Parts, B, C, D, E, H, I, F, G, join these Points one to another, and also to A by right Lines.

2. Divide one of these Parts, as F G, into seven equal Parts, and one of these seven into seven others.

3. Take nine of the larger, and one and a half of the smaller Parts, and with that Distance from F and G, make two Arches to intersect each other in K.

4. From K through F G draw a Circle, divide it into eight Parts equal to F G, and then join them by right Lines: So you will have an Octagon to be a Base to the Pyramid required.

VIII. *To make a Pyramid with an Enneagon for its Base.*

1. From A draw an Arch, and divide it into nine equal Parts, B C D E F G H I K; join these together, and with A by right Lines.

2. Divide any one of these Parts, as K M, into seven equal Parts, and one of them into seven more,

3. Take

3. Take ten of the former, and two of the latter, and from the Points K M make two Arches to intersect each other in M with the Length of those Parts, as a given Distance.

4. From M draw a Circle through K I, which must be divided into nine Parts equal to K I; join these together by right Lines: So you have the Enneagon which was wanted for a Base for the Pyramid required.

IX. To make a Pyramid with a Decagon for its Base.

1. From A draw an Arch, which divide into ten equal Parts, to be joined to each other, and to A, as B C D E F G H I K L.

2. Divide one of these ten Parts into seven, and one of these seven into eight more.

3. Take eleven of the former, and two and a half of the latter, and with that Distance from F G, draw two Arches which shall intersect each other in O.

4. From O draw a Circle through F G, which divide into ten Parts equal to F G, and there will be a Decagon for a Base to the Pyramid.

X. To make a Pyramid with an Endecagon for its Base.

1. From A draw an Arch, and divide it into eleven equal Parts, to be joined each to other, and all to A, as B C D E F G H I K L M.

2. Divide one of them (F G) into seven equal Parts, and one of these seven into seven more.

3. Take

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3. Take twelve of the former, and one and a half of the latter, for a Distance, whereby from F G to draw Arches which shall intersect each other in N.

4. From N draw a Circle through F G, which may be divided into eleven Parts equal to F G, join them together, and you have the Base of the required Pyramid.

XI. *To make a Pyramid with a Dodecagon for its Base.*

1. From A draw an Arch, which divide into twelve equal Parts, which are to be joined to A, and each to other by right Lines, as B C D E F G H I K L M N.

2. Divide any one (F G) into seven equal Parts, and one of these seven into seven others.

3. Take thirteen of the former, and one and a half of the latter, for a Distance whereby from F G to draw two Arches which shall intersect each other in O.

4. From O draw a Circle through F G, and divide it into twelve Parts equal to F G, which when joined by right Lines, will give a Base of the Pyramid that was required.



B O O K

B O O K II.

AS all Rivers have their particular Branches, and every general Science its Divisions, and its Parts; so *Geometry*, generally taken, is the Mother of several other Arts and Sciences, whereof we shall treat in this second Part. These are, Measuring of Heights, of Distances, of Plains, of Solids, of Concaves, and the turning of one Body into another.

C H A P. I.

Of Measuring of Heights.

Meaſuring of Heights is a Science which ſhews how they are to be meaſured: But becauſe there are ſeveral Inſtruments for that Purpoſe, as a Quadrant, a Pantometre, an Aſtrolable, a *Jacob's Staff*, &c. we ſhall at preſent only make uſe of the Aſtrolabe, becauſe it is the ſureſt and the moſt convenient: And we ſhall know how it is to be uſed by the following Problems.

P R O B L E M S.

I. To take the Vertical Height of any Thing, when you can come to the Bottom.

Let the Height of a Tower AB be to be measured

1. Draw a right Line as you please from the Point A , as AC .

2. Measure the Line AC with your Scale, or your Chain, of 26 Feet for Instance.

3. Set the Staff, upon which the Astrolabe is horizontally fastened upon C , so that by the fixed Sights, one may see the Line CA , from one End to the other, as far as the Tower, and that by the two other moveable Sights the Point B , which marks the Height of the Tower, may also be seen.

4. When the Instrument is thus fixed, compute whether the Angle DCE be forty Degrees.

5. Then draw upon a Paper a right Line of the Length of AC , as FG : But this must be done by a small Scale made upon the Paper, or by a Scale of Wood or Latten: Afterwards erect a Perpendicular upon G .

6. Take the Index, and set it directly upon FG , so that the Middle of it may answer to the Point F : Then compute an Angle of forty Degrees equal to DCE as FHI .

7. From F draw a right Line through I , till it touches the Perpendicular G in K .

8. With a small Scale measure the Height of KG , and add the Height of the Staff to which the

the Astrolabe is fastened, and the Sum will give you the Height of the Tower A B.

II. *To measure a Vertical Height where you cannot come at the Bottom.*

Let A B be the Height to be measured; the foot inaccessible, because of a River which hinders all approaches.

1. Draw a right Line upon the Ground, on this Side of the River, as C D; let it be twenty-two Feet long: (Take Notice when you can raise a right-angled Triangle upon this Line, opposite to the Height which you would measure, it is much more convenient, otherwise the Operation is the same.)

2. Set the Instrument upon C, so that by the immovable Sights you may see the Point D directly, and by the two movable ones you may see the Point A beyond the River: When this is done, compute the Angle C E F, which may be of ninety Degrees.

3. Set the Instrument upon D, so that the fixed Sights may make one Line with D C; by the two others you will see the Point A: this Angle ought to have twenty-eight Degrees.

4. Draw upon Paper a Line equal to that drawn in the Field (C D) as G H of twenty-two Feet.

5. With the Index take an Angle at H equal to the Angle A C D, viz. of ninety Degrees, as I H K, and lengthen the Side H K. Afterwards upon the Point G take another Angle of twenty-eight Degrees, equal to the Field-Angle O D P, as G L M, and then lengthen the Side G M till it cuts

cuts the other HK, in N, and this Point N will mark the Foot of the Height A.

6. Having the Distance from the Instrument to the Foot of the Tower, it will be an easy Thing to work the rest by the foregoing Problem.

II. *To measure a Perpendicular Height, where you can come at the Bottom, with the Shadow of a Staff.*

1. Fasten a Staff a Foot longer perpendicularly into the Ground, as AB, and measure the Shade by the Staff, three Feet for Instance.

2. With the Shade of the Staff, viz. three Feet, measure the Shade of the House DE, whose Height you would know; and as many Feet as the Shade of the House exceeds the Shade of the Staff, so many Feet high will the House be: For Instance, if the Shade of the House be twenty-four Times longer than that of the Staff, then we ought to say that the House is twenty-four Feet high.

Or thus.

1. Erect a Stick, divided into ten equal Parts, Feet, or Inches, perpendicularly in the Ground, and at the same Time measure the Shade caused by this Staff, twenty Feet for Instance.

2. Measure also the Shadow of the House, whose Height you would know, for Instance thirty-eight Feet.

3. By the *Rule of Three* say, If the Shadow of twenty Feet gives a Height of ten Feet, what will the Shadow of thirty-eight Feet give? *Ans.* nineteen Feet.

IV. *To measure the Inclination of a Mountain.*

Let the Inclination of the Mountain A B be to be measured.

1. Draw from the Point A, which stands for the Foot of the Mountain, a right Line, thirty-six Feet long, as A C.

2. Set the Instrument upon the Point A, and look through the two fixed Sights towards the Point C, and through the two movable ones towards the Point B, the Top of the Mountain; this Angle, for Instance, may be 110 Degrees.

3. Then set the Instrument upon C, and look through the two fixed Sights upon the Foot A, and through the two other fixed ones upon the Top B: Then compute the Angle, which may be, for Instance, forty Degrees.

4. Afterwards draw a Line upon Paper thirty-six Feet long, because it ought to be equal to the Line A C, as D E.

5. Then with your Instrument at the Point D make an Angle equal to that of the Figure at A, viz. 110 Degrees, as G D F.

6. Upon the Point E, set another Angle of forty Degrees, equal to that at C, as I E H.

7. Produce the Sides D F and E I, and where these lengthened Lines intersect one another, as at K, draw from that Point to D a right Line, which will represent the Inclination which was required, provided the Height of the Staff upon which the Astrolabe was fastened, be added.

V. To measure the vertical Height of a Mountain.

This Problem must be wrought as the foregoing one, provided that you let fall a Perpendicular from the Point K, which marks the Top of the Mountain, which must touch the Line CD produced to L; the Line K L will represent the vertical Height of the Mountain.

VI. To measure the Height of a Tower built upon a Rock.

Let the Height B D be to be measured.

1. Seek the inclining Height of the Mountain by *Prob. 4.* and let the Triangle A B C serve for its Operation.
2. Make the Triangle H I K upon Paper equal to the Triangle A B C.
3. Measure the Field-Angle C B D, for Instance thirty-eight Degrees.
4. Upon K, which represents the Point B, and so by consequence the Top of the Mountain, raise a Perpendicular of what Height you please.
5. With your Instrument make upon the Point an Angle equal to the Angle of the Figure A B C D, viz, L I M.
6. Lengthen the Side I M till it touches the Perpendicular raised upon K in N.
7. Measure the Line N K, it will give you the Height of the Tower B D, if you add to it the Height of the Staff.

VII. To

VII. *To make the depth of a Well.*

1. Measure its Diameter A B, nine Feet for Instance ; and find the Angle A B E of ninety Degrees.
2. Set the Instrument so upon A, as that by the two fixed Sights you may see the Point B, and by the two movable ones you may see the Bottom of the Pit E, and let this Angle be sixty Degrees, as H A I.
3. Draw a Line nine Feet long upon Paper, which shall represent the Diameter A B, as F G.
4. From F let fall a Perpendicular which may represent the Depth B E.
5. Make an Angle at G equal to the Angle K G L, viz. of sixty Degrees, as H A I.
6. Lengthen the Side G L, and where this lengthened Line meets the Perpendicular F, in M, measure from M to F, and you will have the Depth of the Well.

C H A P. II.

Of measuring of Distances.

Meaſuring of Diſtances, is a Science which teaches to meaſure the Diſtance of one Place from another, in an open Field.

P R O B L E M S.

- I. *To meaſure the Diſtance of one Place from another, where they are both acceſſible.*

Let the Diſtance from A to B, be to be meaſured.

D 2

1. From

1. From A draw a right Line, what you please, and measure with a Chain or Scale; suppose twenty-two Feet in Length, as AC.

2. Set the Staff upon which the Astrolabe is fixed upon the Point A, so as that by the two fixed Sights you can only see directly forward towards the Point C, and by the two others the Point B: Then count the Angle d A e, suppose ninety Degrees.

3. Remove the Instrument upon C, and look through the fixed Sights towards A, and through the movable ones towards B; then compute this Angle f c g, suppose twenty-two Degrees.

4. Draw a Line upon Paper twenty-two Feet long, equal to the Line AC, as HI.

5. With the Reporter upon the Point H draw an Angle equal to the Angle d A e, that is to say, of ninety Degrees, as k H l: Do the same Thing at I, where make another Angle equal to the Angle e f g, *i. e.* of twenty-two Degrees, as m I h.

6. Lengthen the Sides HK, IM, and from the Point where these two lengthened Lines intersect each other, as O, to the Point H, measure the Distance, which shall be equal to the Length AB.

II. *To measure the Distance of two Places, whereof one is inaccessible.*

Let the Distance from A to B be that which is required, and B inaccessible, because of a River which hinders all Approaches.

1. From A draw a right Line twenty-two Feet long, as AC.

2. Set

2. Set your Instrument upon A, and look through the two fixed Sights upon the Point C, and through the two movable ones upon B: Then compute the Angle D A E of ninety-three Degrees.

3. Carry the Instrument to C, and look through the two fixed Sights upon the Point A, and through the two others upon B, and then compute the Angle F C G of thirty-three Degrees.

4. Draw upon Paper a Line equal to A C, *i. e.* of twenty-two Feet, as H I.

5. Upon H make an Angle equal to the Angle of the Figure D A E, *i. e.* of ninety-three Degrees, as K H L: So also upon I make another Angle equal to the Angle F C G, as M I N.

6. Lengthen the Sides H K and I M, and in the Place where they intersect, as at O, let fall a Perpendicular upon H, which will give you the Distance A B.

III. *To find the Distance of two Places which are both inaccessible.*

Let the Distance A B be to be measured.

1. Take a fixed Point C, from which draw a right Line C D, which shall be thirty-three Feet long.

2. Set the Instrument upon C, and look through the two fixed Sights upon the Point D, and through the two others upon the Point A: Then compute the Angle K C H, for Instance of ninety Degrees.

3. Leave the Instrument as it is, and remove the movable Sights, till through them you may see the Point B, and then compute that Angle, for Instance thirty-six Degrees, as i C H.

4. Carry the Instrument to D, and fit it so, as that through the fixed Sights you may see the Point
D 3 C, and

C, and through the two other movable ones the Point B: Then compute this Angle, which may be of 100 Degrees, as g D E.

5. Leave the Instrument as it is, and turn the movable Sights till you may see the Point A through them; then compute that Angle, of thirty Degrees, as f D e.

6. Afterwards draw a Line of thirty-three Feet upon Paper, to represent the Line CD, as L M.

7. With the Reporter set two Angles at L, one of ninety Degrees, and the other of thirty-six Degrees, so that the first n L O may represent the Angle HCK, and the other NLP the Angle ICH.

8. Lengthen the Sides L O and L P.

9. Add two Angles to the other Point N, one of 100 Degrees, as q m r to represent the Angle of the Figure EDG, and the other of thirty Degrees, as q M S, to represent the Angle e D F.

10. Lengthen the Sides MR, M S, and observe where these two lengthened Lines touch the two first, as at T V. For this Distance T V will give you the Distance A B, which was required.

IV. To measure the Breadth of a River with a Staff.

1. Fix a Staff perpendicularly upon the Bank of a River, as A.

2. Cleave it at the End, and fasten a Cross-Staff into the Cleft, as B C.

3. Stand behind the small Cross-Staff B C, and use it as you would the Sights of an Astrolabe, *i. e.* move it downwards, till from B C you can see the other Side of the River at P A.

4. Afterwards letting the small Staff stand as it is, turn the large one perpendicularly, till from
B C

BC you can see the whole Length of the Bank : Then stand behind B, and observe the last Place, where from C you can see the Bank on the other Side, as at E.

5. Measure the Distance EA, it will give you the Breadth of the River AD.

V. To describe a Figure taken from the Field upon Paper.

Let the Figure to be described be ABCDE.

1. Set the Staff to which the Astrolable is fixed, upon the Point E, and look upon the Point D through the fixed Sights, and through the two movable ones upon the Point A. Then compute this single Angle AED, sixty Degrees, for Instance.

2. Measure the Line AE of twenty-three Feet.

3. Measure another Line ED of twenty-three Feet.

4. Set the Instrument upon D, and look towards C with fixed Sights, and with the movable ones towards E : Then compute this Angle, of seventy Degrees, for Instance, as CDE.

5. Let the Side DC be of twenty-eight Feet.

6. Seek the Angle bCd after the aforesaid Manner, and let it have fifty Degrees.

7. Measure the Line CB, for Instance, of thirteen Feet.

8. The Side BA will be found of itself.

When this is done in the Field, then

1. Draw a Line upon Paper twenty-three Feet long, to represent the Figure AE, as KF.

2. With your Instrument make at the Point F an Angle equal to the Angle of the Figure dEa, *i. e.* of sixty Degrees, as KFG.

D 4

3. Lengthen

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3. Lengthen the Side of this Angle Fg, and add its Length to it, *i. e.* twenty-four Feet, as FG.

4. Upon G make an Angle equal to that of the Figure e Dc, *i. e.* of seventy Degrees, as f G h.

5. Lengthen the Side Gh, and add the Side DC, *i. e.* of twenty-eight Feet, as GH.

6. Upon the Point H set another Angle equal to that of the Figure d Cb o. fifty Degrees, as g H i.

7. Lengthen the Side Hi, and add thirteen Feet to it, as HI, which may represent the Side CB.

8. Join IK together by a right Line, which will give the last Side of the Figure BA, and which at the same Time will entirely represent the given Figure upon Paper.

VI. *To describe upon Paper a Figure taken from the Field, which is inaccessible.*

Let the Figure ABC be to be described upon Paper from the Point D.

1. From D draw a Line DE thirty-two Feet long.

2. Set the Instrument upon D, and look through the fixed Sights towards E, and through the two movable ones towards A: Then compute the Angle gDf, of 105 Degrees.

3. Leave the Instrument as it is, and remove the movable Sights till you can see the Point B, and compute the Angle gDh of ninety Degrees.

4. Leave the Instrument still as it is; look through the movable Sights towards the Point C, and compute the Angle gDi of sixty Degrees.

5. Set the Instrument upon E, and look through the fixed Sights towards the Point D, and through the movable ones towards A, and compute the Angle kEl, for Instance, of fifty Degrees.

3 6. Leave

6. Leave the Instrument as it is, and look through the movable Sights towards B, and compute this Angle mEk of seventy Degrees.

7. Look through the same Sights towards the Point C, and then compute the Angle kEn , for Instance, of ninety Degrees.

This being done in the Field, then

1. Draw a Line of thirty-two Feet upon Paper, as OP , equal to the Line DE .

2. Take an Angle of 105 Degrees at O , as qOr , which may represent the Angle of the Figure fDg , and lengthen the Side Oq .

3. Leave the Reporter as it is, and compute another Angle of ninety Degrees, as rOs to represent the Angle gDh , and lengthen the Side Os .

4. Seek the last Angle of sixty Degrees rOt , which may represent the Angle of the Figure gDI , and lengthen the Side Ot .

5. Set the Reporter upon the Point P , and compute an Angle of fifty Degrees, to represent the Angle lEk , as aPb ; lengthen the Side Pb till it meets with the Side Oq in C : For this Point of Intersection will mark the Point A .

6. Leave the Reporter as it is, and compute another Angle of seventy Degrees, which may represent the Angle mEk , as aPd ; lengthen the Side Pd till it cuts the lengthened Line Os in E , which Point will mark the Point B in the Figure.

7. Compute another Angle of ninety Degrees equal to the Angle nEk , as Pf ; lengthen the Side Pf till it meets with the lengthened Line Ot in G , which answers to the Point C in the Field-Figure.

8. Join

8. Join CE , EG , and GC together, and you shall have your Figure ABC represented upon Paper.

C H A P. III.

Of measuring of Plains.

Meaſuring of Plains is a Science which teacheth us to meaſure, all Sorts of Surfaces of Things, which Geometricians call *Areas*.

P R O B L E M S.

I. *To meaſure the Area of a right-angled Triangle ABC .*

1. Measure the Line AB , twelve Feet long for the Base.

2. Measure the Perpendicular BC , of eight Feet.

3. Multiply the half of the Base by the whole Perpendicular, or the half of the Perpendicular by the whole Base, by the Sum (forty-eight Feet) will be the Area of the Triangle which was desired.

II. *To meaſure the Area of an oblique-angled Triangle DEF .*

1. Let fall a Perpendicular from F to its opposite Side DE , which may divide the Triangle into two right-angled Triangles, DGF , and FGE .

2. Measure these two Triangles by the foregoing Problem, *i. e.* multiply the whole Base DG and GE by the half of the Perpendicular FG , or the whole Perpendicular by the half of the Bases DG and DE .

Thus

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Thus for Instance : Let the Base DG be twelve Feet, and the Perpendicular FG ten. Take the half of the Perpendicular, *i. e.* five Feet, and multiply it by the Base of twelve Feet, and the Sum will be sixty Feet, which gives the Area of the Triangle DFG .

3. Let the Base GE of the Triangle FGE be six Feet, and the Perpendicular FG stands as it did, *i. e.* to Feet. Multiply five by six, or three by ten; the sum will be thirty Feet, which will give the Area of the Triangle. Then add thirty to sixty, the Sum ninety will be the Number of Feet in the whole Area of the given Triangle DEF .

III. *To measure the Area of an equilateral right-angled Square $ABCD$.*

Multiply one Side by the other : AB for Instance, of twelve Feet, by BC of twelve Feet, because the Sides are equal : The Product 144 Feet will give you the Area which is sought for.

IV. *To measure the Area of a Parallelogram $ABCD$.*

Multiply the shortest Side BC of six Feet, by the longest Side AB of twelve Feet: The Product seventy-two Feet will give you the Area of the Parallelogram which was required.

V. *To find the Area of a Rhomb, $ABCD$.*

1. Let fall a Perpendicular from A to the Line DC , as AE .

2. Let fall another Perpendicular from B equal to AE , as BF ; and join CF together. So that
3 instead

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instead of a Rhomb you have a Parallelogram $ABEF$: Then work by the foregoing Problem. See *Prob. 28. Book 1. Chap. 2.*

VI. *To find the Area of a Rhomboid $ABCD$.*

1. Let fall a Perpendicular from A to the opposite Line DC , as AF .
2. Let fall another from B , equal to AF , as BE .
3. Join CE together, and instead of the Rhomboid $ABCD$ you have a Parallelogram $ABEF$: You will find its Area by the fourth Problem of this Chapter.

VII. *To find the Area of any unequilateral Quadrangle.*

Let the given Quadrangle be $ABCD$.

1. Divide this Quadrangle into two Triangles ABD , and CDB .
2. Divide each of these Triangles into two right-angled ones, as ABF , BCE , ADF , DEC .
3. When you have these four right-angled Triangles, search their Areas by the two first Problems of this Chapter: Then join the Sum of all these Triangles together, and it will give the Area which is required.

VII. *To find the Area of any regular Polygon.*

Let the regular Pentagon demanded be $ABCDE$.

1. Measure one Side of the Polygon as AB , for Instance, six Fathoms: Multiply this Number by the Number of the Sides of the Polygon, as here by five, because this Polygon has but five Sides: The Product of this Multiplication will give you the Length of all the Sides.

2. Let

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2. Let fall a Perpendicular from any Side to F the Center of the Polygon, as FG: Then measure this Line, five Fathoms, for Instance.

3. Multiply the Sum of all the Sides, by the half of the Perpendicular: The Product will give the Area which is required.

IX. To find the Area of any irregular Polygon ABCDE.

1. Divide the whole Figure into right-angled Triangles; as this irregular Pentagon ABCDE into ABG, BCG, ADH, CDH, AEF, and DEF.

2. When you have only right-angled Triangles, work by the first Problem of this Chapter; the Sum of all the Triangles reduced to one, gives the Area which is sought for.

X. To find the Area of a Circle.

Reduce this Circle to a right-angled Triangle, by *Prob. 21. Book 1. Chap. 2.* and then seek the Area by the Rules of the first Problem of this Chapter.

XI. To find the Area of an oval Figure.

1. Divide the proposed Figure into four equal Parts, as ABCD, so as that the Line AB may make one Diameter, and CD another.

2. Seek for a mean Proportional between these two Diameters; which you may thus find:

Set the Diameter AB upon a long Line, and upon the same Line from the Point B set the other Diameter CD, as BC; then take the half of the Distance between A and C, and carry it on to B, as EB; this shall be a mean Proportional;

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tional; then divide EB into two equal Parts, as EF , FB ; then draw a Circle from the Point F through the Point E , which shall be equal to the given oval Figure.

3. Having this Circle, find its Area by the foregoing Problem, *i. e.* raise a Perpendicular upon B , one extreme Point of this Diameter, which shall have thrice the Length of the Diameter AB , and a seventh Part over, as BG .

4. Join F the Center of the Circle to the Point G by a right Line, which shall give a right-angled Triangle equal to the given Circle; its Area may be found by the Rules of the first Problem of this Chapter.

[This Triangle which he says is equal to the Area of the Circle is not expressed in the Scheme.]

XII. *To measure the Surface of any equilateral Pyramid.*

1. Let $ABCD$ be an equilateral Square, which shall be the Base of the Pyramid given.

2. Find the Area of this Base by Prob. 3. of this Chapter, of forty-eight Feet.

3. Multiply one of its Sides, as AB , by the Height of the Pyramid EF , that is, 12 by 28, whose Product will be 336 Feet.

4. Multiply 336 by 4, the Number of the Sides of this Pyramid, and the Product will be 1344 Feet.

5. To this Sum add the Area of its Base, forty-eight Feet, and you will have the total Sum of the Area of the Pyramid proposed, *viz.* 1392 Feet.

XIII. *To find the Convex Surface of a right-lined Cylinder.*

1. Set the Height of the Cylinder BD upon a long Line.

2. Set

2. Set upon the same Line, beginning at the Point D, the Diameter of the Base of the Cylinder marked CD, as DE.

3. Divide the Line EB into two equal Parts, BF, EF.

4. With the Distance FD draw a Circle, which shall contain the Convex Surface of the given Cylinder: This you may find by *Prob. 21. Chap. 2.* of the first Book, which teaches you to make a right-angled Triangle equal to a given Circle: When you have this Triangle, find its Area by *Prob. 1. of this Chapter.*

5. When you have the Area of this right-angled Triangle, which represents the Convex Surface of the Cylinder, then find the Area of the two Bases of the Cylinder by *Prob. 1. of this Chapter*: Add the Sum of the two Bases to the Area of that Triangle which gives you the Convex Surface of the Cylinder, without counting the Bases, and you will have the general Sum of the whole Surface of the Cylinder, with both its Bases. See *Archimedes de Sphæra & Cylindro, Lib. i. Prop. xiii.*

XIV. To find the Convex Surface of a regular Cone.

Let the given Cone be ABD, and its Diameter AD.

1. Set the Height of the Cone DB upon a right Line.

2. Set its Semi-diameter CD upon the same Line, as DE.

3. Divide EB into two equal Parts, EF, FB.

4. Take the Distance FD, and make a Circle in large as the Cone without the Base.

5. Reduce

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5. Reduce this Circle to a right-angled Triangle by *Prob. 21. Chap. 2.* of the first Book, and find its Area by *Prob. 1.* of this Chapter.

6. By the two forementioned Problems seek the Area of the Base of your Cone, and add this Sum to the former; the Sum total will give the whole Surface of the given Cone. See *Archimed. Lib. cit. Prop. xiv.*

XV. To measure the Convex Surface of a Globe.

1. Measure the Diameter A B, of nine Feet.

2. Find the Circumference of the Circle, whereof that is the Diameter, which is always thrice as long, and a third Part over.

3. Multiply the Diameter by the Circumference; the Product will give you the required Surface of the given Globe.

XVI. To find the Area of any Trapezium as A B C D.

You must work by the Rules of Problem 7. of this Chapter.

XVII. To find the Area of the Base of a round Tower, where you can only come at one Part.

1. Measure the Line A B, of fourteen Fathoms, and from its middle Point draw a Perpendicular to the Arch, as D C, of four Fathoms.

2. Multiply the Distance A D by the Remainder D B, *i. e.* 7 by 7; then divide by 4 the Number of the Perpendicular D C.

3. Add to this the Length of the Perpendicular, *i. e.* four Fathoms, and it will give you the Length of the Diameter, to compleat the Base.

4. When

4. When you have found the Base, seek for a right-angled Triangle, equal to it, by Prob. 21. Chap. 2. Book 1; afterwards you may find the Area of that Triangle by Prob. 1. of this Chapter.

C H A P. IV.

Of measuring of Solids.

Meaſuring of Solids is a Science which ſhews how one is to find the Solidity of Bodies: Solidity is Magnitude with Breadth, Length, and Thickneſs.

P R O B L E M S.

I. To find the Solidity of a Parallelepiped.

1. Measure the Height, Length and Breadth of the Parallelepiped.
2. Multiply the Breadth AD, of two Feet, by the Length AB, of four Feet, and the Sum will give you the Area of the Baſe.
3. Multiply the Number of this Area by the Height of the Parallelepiped, which here ſhall be eight Feet; and the Product from thence will ſhew you the Solidity required, of ſixty-four Feet.

II. To find the Solidity of a Priſm.

1. Find the Area of the Baſe ABC, by Prob. 2. Chap. 3. Book 2. of ſix Feet.
2. Measure the Height CF, here of nine Feet.
3. Multiply

3. Multiply the Base by its Height, *i. e.* 6 by 9, and the Product 54 will give the Solidity required.

III. *To find the Solidity of a Cylinder.*

1. Find the Area of the Base by Prob. 21. Book 1. Chap. 2. and by Prob. 1. Chap. 3. Book 2. for Instance five Feet.

2. Find the Height of the Cylinder A B, here of nine Feet.

3. Multiply the Area upon the Height, *i. e.* 5 by 9, and the Sum 45 will give the Solidity required.

IV. *To find the Solidity of Pyramids and Cones.*

1. Measure their Height F E and A B, for Instance, of twelve Feet.

2. Find the Area of their Bases; that of the given Pyramid by Prob. 6. Chap. 3. Book 2. of sixteen Feet; and that of the Cone by Prob. 10. Chap. 3. Book 2. of sixteen Feet.

3. Multiply the entire Height by the third Part of the Base, *i. e.* twelve Feet by five Feet four Inches; or the whole Base by the third Part of the Height, *i. e.* sixteen Feet by four Feet; the Sum sixty-four Feet will give the Solidity of the Pyramid and the Cone; for this is equal to the given Pyramid: And because we are to find its Solidity, that also will be equal to the Solidity of the same Pyramid.

V. *To find the Solidity of a Globe.*

1. Multiply the Semi-diameter A B by the Surface of the Globe, which you shall find by Problem 15. of the foregoing Chapter.

2. Di-

2. Divide this Sum by 3, and the Quotient will give you the required Solidity: For Instance, let the Semi-diameter be 28 Feet, and the Convex Surface 9856 Feet; multiply this by 28, and the Product will be 275968; divide that by 3, and your Quotient 91989 $\frac{2}{3}$ will give you the Number of Feet which make up the Solidity of this Globe.

VI. *To find the Solidity of a Tetraëdram.*

Since a Tetraëdram is nothing else but a Triangular equilateral Pyramid, its Solidity must be sought by Prob. 4. of this Chapter, *i. e.* by multiplying the Base by a third Part of the Height, or the Height by a third Part of the Base; the Product will shew the Solidity which is required.

VII. *To find the Solidity of an Octaëdram.*

Since an Octaëdram is made up of two Pyramids which have one common Base, *i. e.* an equilateral right-angled Square,

1. Find the Solidity of one of these Pyramids by Prob. 4. of this Chapter, for Instance, of sixteen Feet.

2. Multiply these 16 Feet by 2, the Product will give the required Solidity of 32 Feet.

VIII. *To find the Solidity of a Dodecaëdram.*

If one draws from the Center of a Dodecaëdram a right Line to every angular Point, one may form twelve equal Pyramids, every one whereof will have a regular Pentagon for its Base; upon which Account,

1. Find the Solidity of one of these twelve Pyramids, by the same fourth Problem ; and let it be, for Instance, of twelve Feet.

2. Multiply these twelve Feet by the Number of the Pyramids, *i. e.* 12 ; the Product 144 gives the required Solidity.

IV. *To find out the Solidity of an Icosaëdram.*

This being formed of twenty equal *Tetraëdra*, if one draws right Lines from its Center to every angular Point, one must,

1. Find the Solidity of one of these *Tetraëdra* by the same fourth Problem, for Instance, of eight Feet.

2. Multiply 8 by 20, the Number of the *Tetraëdram* ; and the Product 160 will shew the Number of the solid Feet in the given *Icosaëdram*.

X. *To find the Solidity of a Cube.*

By the third and fourth Problems of the foregoing Chapter, multiply the Area of the Base by the Length, and the Product gives the Solidity.

XI. *To find the Solidity of a solid Rhomb, and Rhomboid.*

Find the Area of the Base of a Rhomb by Prob. 5. of the foregoing Chapter, and the Area of the Base of the Rhomboid by Prob. 6. of the same : When they are found, multiply them by their respective Lengths, as was directed in the foregoing Problem, and the Product gives the Solidity required.

XII. *To*

XII. *To find the Solidity of a Wall, Rampart, Cour-
tain, &c.*

This is done by Problem 1. of this Chapter.

C H A P. V.

Of measuring Concave Bodies.

MEasuring Concave Bodies is a Science which teaches us to find their Capacity, that so we may know how much they contain: Cylindro-metrical Bodies have need of a Cylindro-metrical Scale; and Cubo-metrical Bodies have need of a Cubo-metrical Scale: So that these two Scales are made use of in the measuring of Concave Bodies.

P R O B L E M S.

I. *To find the Capacity of a Concave Parallelepiped.*

By which I understand all square Bodies; as Chambers, Granaries, Cellars, Towers, Pits, &c. So that if one would know how much they contain, he must,

1. With his Cubo-metrical Scale measure the Height, Length, and Depth.
2. Multiply the Length by the Breadth, and their Product by the Height.
3. Examine how many Measures the whole Sum takes up upon the Scale, and so the required Capacity may be found.

E 3

II. *To*

II. To find the Capacity of a Ditch.

1. Measure its Breadth at the Top, AF, fifteen Fathoms and one Foot.
2. Measure its Breadth at the Bottom CD, eleven Fathoms five Feet.
3. Measure its Depth CG, nine Fathoms.
4. Measure its Length, 496 Fathoms.
5. Add the two Breadths together, and multiply the half of the Sum by the Length of the Ditch; there will be 6438 Fathoms.
6. Multiply these 6438 Fathoms by the Depth 9 Fathoms, and the Product will be 57942 Fathoms, or 347652 Feet, which gives the Capacity required.

III. To find the Capacity of Columns, Towers, and other Prisms.

1. With a Cubo-metrical Scale measure the Height of the Prism.
2. Find the Area of the Base.
3. Multiply that Number by the Height, and you will find the Capacity.

IV. To find the Capacity of any regular Pyramid.

1. Measure the Area of the Base with a Cubo-metrical Scale.
2. Measure the Height likewise the same Way.
3. Multiply the Height by the Area of the Base.
4. Divide the Product by three, and the Quotient will give you the Capacity.

V. To

V. To find the Capacity of a Cone.

1. Measure the Area of the Base with a Cubo-metric, or Cylindro-metric Scale.
2. Multiply this Number by the third of the Height, and you have the Solidity.

VI. To find the Capacity of a Cylinder.

1. With a Cylindro-metrical Scale find the Area of its Base.
2. Multiply that by the Height of the Cylinder; the Quotient gives its Capacity.

VII. To find the Capacity of a Truncated Cone whose Vertex is cut off.

1. Find the Area of each Base by the Cylindro-metric Scale.
2. Add the Sums together, and multiply its Height by the half of that Sum; the Quotient will give its Capacity.

VIII. To find the Capacity of a Barrel whose Heads are equal.

We must take Notice that the Rod by which a Vessel is to be gauged, is marked with different Measures; and so one Side of the Gauging-Rod is for the Length of a Barrel, and the other for Depth: In answer therefore to the Question proposed,

1. Measure the Area of the Bottom A B.
2. Measure the Thickness with the Gauging-Rod, and by that take the Surface of the Belly of the Barrel.

E 4

3. Add

3. Add these two Sums together, and multiply the half by the Length of the Vessel, so the Product gives you its Capacity.

IX. *To find the Capacity of a Barrel whose Heads are unequal.*

1. Measure the Diameter of the Head A, and by this known Diameter measure its Surface.

2. Measure the other Diameter EF, and thereby find the Area of that Head.

3. Add these two Sums together.

4. Find the Depth of the Barrel CD, by which you find the Surface of its Circumference; by Prob. 22. Chap. 2. Book 1. and by Prob. 10. Chap. 3. Book 2.

5. Add the Sum of this Surface to the Sum of the two Heads; then multiply the half of all these added together, by the Length of the Barrel: This will give you the Capacity.

C H A P. VI.

Of TRANSMUTATION.

TRansmutation is a Science which teaches us to encrease or diminish any given Figures, or to give them another Form. We ought to take Notice, that what is here said of Figures, may also be understood of Bodies, when one would give them another Shape which they had not before; But since we produced somewhat of this Matter in Chap. 2. Book 1. from Prob. 21. to the End of the

the Chapter, we shall at present only treat of the Transmutation of Bodies.

P R O B L E M S.

I. *To turn a Cylinder into a Parallelepiped of the same Height.*

1. Instead of the Base of the Cylinder CBA , make a Square $ABCD$, by Prob. 23. Chap. 1. Book 1.

2. Raise upon $ABCD$ four Perpendiculars of the Height of AB , which may represent the Height of the Cylinder, as $EFGH$.

3. Join EF , EH , FG , and GH together by right Lines ; and you have the Parallelepiped.

II. *To turn a Cone into a Pyramid of the same Height.*

1. Make a Triangle, Square, Pentagon, or what other Polygon you please, equal to the Base of the Cone CBD , and let it be the Base of a Pyramid, as $ABCD$.

2. Raise from the Middle of the Base F a Perpendicular, of the Height of the Cone BA , as FE ; then draw from $ABCD$ Lines to the Point, and the Pyramid is made.

III. *To turn a Parallelepiped into a Cylinder.*

Make a Circle equal to the Base of the Parallelepiped, and raise this Circle to be as high as the Parallelepiped, and the Work is done.

IV. *To*

IV. *To turn a Pyramid into a Cone.*

1. Make a Circle equal to the Base of the Pyramid.
2. Raise upon its Center a Perpendicular as high as the Pyramid, as B A.
3. Draw the Extremities of the Diameter C D together till they meet at the Top of the Perpendicular A, and the Cone will be finished.

V. *To turn a Prism or a Cylinder into a Pyramid or a Cone of the same Height, or the contrary.*

1. Enlarge the Base of the Cylinder three Times as much as it is, by Prob. 1. Chap. 2. Book 1.
2. Upon its Center raise a Perpendicular as high as the Cylinder, and draw the Extremities of the Diameter together to the Top of the Perpendicular, and the Pyramid will be made: In like Manner you may turn a Cylinder or a Prism into a Cone: On the contrary, when you would make a Prism or a Cylinder equal to a Pyramid or a Cone, you must make the Base of the Pyramid or of the Cone three Times less, and then upon this Base erect a Cone or Pyramid of the Height of the Prism or Cylinder given.

VI. *To make a Cube equal to a Parallelepiped.*

1. If the Base of the Parallelepiped be square, find a mean Proportional between its Height and one Side of the Base; this mean Proportional will be the true Measure of the Cube required.

2. If

2. If the Base be only a Parallelogram, turn it into a Square by Prob. 25. Chap. 2. Book 1. then go on as at first, and your Work will be done.

VII. *To make a Cube equal to a Cylinder given.*

1. Make a Parallelepiped equal to a Cylinder given, by Problem 1. of this Chapter.

2. Afterwards make a Cube equal to that Parallelepiped, by the precedent Problem, and you have the Cube desired.

VIII. *To make a Cube equal to a given Cone.*

1. Make a Parallelepiped equal to a given Cone, by Problem 5. of this Chapter.

2. Afterwards make a Cube equal to that Parallelepiped by Problem 6. of this Chapter.

IX. *To make a Cube equal to a Pyramid.*

This Problem must be wrought like the last foregoing.

X. *To make a Cone equal to a Globe.*

1. Take one of the great Circles of your Globe, and make it four Times bigger, by Prob. 11. Book 1. Chap. 2.

2. Raise a Cone upon this Base as high as the Semi-diameter of the Globe A B.

3. The Cone C D E will be equal to the Globe A B D.

XI. *To*

XI. To make a Cube equal to a given Globe.

1. Make a Cone equal to a Globe, by the foregoing Problem.
2. Make a Parallelepiped equal to this Cone, by Prob. 5. of this Chapter.
3. Lastly, make a Cube equal to this Parallelepiped, by Prob. 6. of the same Chapter.

Here we conclude our *Treatise of Geometry*, being persuaded, that the Things which we have said, will be enough for those who would make any Progress in Fortification.



A N E W

A NEW
TREATISE
OF
FORTIFICATION.

BOOK I.

CHAP. I.

Sect. 1. *Of the Definition of military Architecture.*

Fortification, or military Architecture, is an Art which teaches Men to fortify themselves with Ramparts, Parapets, Moats, Covert Ways and *Glacis's*, to the End the Enemy may not be able to attack any Part without great Loss of his Men; and that the small Number of Soldiers which defend the Place may be thereof able to hold out for some Time.

Sect. 2.

Sect. 2. *Of the Original of Fortification.*

CERTAIN it is, that Fortification was originally very inconsiderable; for in regard that Men had nothing to fear at that Time but the Assaults of wild Beasts, and Robbers, they had no other Fortifications than simple Hedges, which continued still in Use 328 Years before our Saviour; at what Time *Alexander the Great* found the *Hircanians* and *Mardians* fortified after that Manner, *Q. Curtius*, Lib. vi. Cap. v. Afterwards they fortified themselves with Walls, those Hedges being easy to be cut down. But Ambition increasing, in regard that they who coveted Dominion over others, soon found a Way to leap over these feeble Defences, they added a Moat, and in making this Moat they raised at the same Time a Rampart, behind which the Besieged placed themselves, to annoy the Enemy with their Arrows. The Enemy, not able to surmount these Obstacles, resolved to venture some Arrows to pass the Moat, and lodge themselves at the Foot of the Wall, whence the Besieged could not chase them, notwithstanding the great Number of Stones which they threw down to annoy the Assailants, because the Enemies covered themselves with their Bucklers which they held over their Heads. This obliged those within to make Holes in the Walls, and through them to shoot their Arrows at the Enemy to hinder them from attacking them. For which Way soever they came, the *Arbalesta* annoyed them. Nevertheless the Foot of the Walls were without Defence, so that the Enemy lodging themselves between the nearest Holes, they bethought themselves of making

making square Towers with Holes on every Side : For they stood at the Head of the Walls, to hinder the Enemy from lodging between the Holes in the Wall. True it is, that they soon invented certain Engines, which we call at this Day Battering Rams, which were strengthened at the Head with a massy Point of Iron, and so pushed against the Walls of those square Towers, till they brought them to Ruin. After which they made Roundels, which were looked upon as a stronger Sort of Fortification, till Power began to be known in Europe. For we find in History, that in the Year 1380, under the Reign of *Wenceslaus*, the Son of *Charles IV.* a certain *Franciscan* Monk, whose Name was *Berthold Schwartz*, of *Friburg in Brisgau*, shewed the first Use of Powder to the *Venetians*, then at War with the *Genoeses*. After which they made Cannon to batter Places; the furious Execution of which, ranversed like a Clap of Thunder those feeble Walls; which obliged them that were attacked with these astonishing Engines, to erect a good Rampart behind their Walls, and to make the same Walls much thicker than before.

This Manner of Fortification would have subsisted a long Time, had it not had one Defect; which was, that those Round Towers had one Part in the Form of a Triangle, which could not be seen by those within; and which the Enemy coveted to batter, on purpose that he might lodge himself secure from the Shot of the Besieged, who could not see him in that Part. To correct this Default, they filled that defective Part with good Earth, which being environed with a good Wall, formed also two Points which looked toward the Field, as now do the Faces of a Bastion, and

and which covered that Part. The Enemy seeing that, began to attack those two Faces first of all: So that the Besieged found themselves obliged to add Flanks to those Faces, to plant Cannon upon them, and prevent the Enemy from doing so much Mischief to the Faces as before. And thus the Bastions were invented, as we see them at this Day built upon the Angle of the Gorge.

Sect. 3. *Of the Parts of Fortification.*

TH E R E are three Parts of it; that is to say, *Ichnography*, *Orthography*, and *Scenography*.

Ichnography is what we call the Plane, or Representation of the Length and Breadth of a Fortrefs, of which the Parts are marked out either upon the Ground, or upon Paper.

Orthography is called the Profil, or the Representation of a Fortrefs made and raised, so that a Man may see the Length, the Breadth, and Height of its Parts.

Scenography is the Perspective of the Parts of a Fortrefs.

Sect. 4. *Of the Division of military Architecture.*

FORTIFICATION is Regular or Irregular:

Regular is that where all the Sides, and all the Angles that compose it, are equal one to another.

Irregular is that where all the Sides and Angles are not all equal nor uniform one to another. And it is either durable or temporary.

Durable is that which is built to continue a long Time.

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Temporary is that which is erected in case of Necessity for a little Time : And under this Signification are contained all sort of Works erected for the seizing upon a Passage, or some Hill, or when they make Circumvallations, and Countervallations ; that is to say, Redoubts, Trenches and Batteries.

C H A P. II.

Of the Parts of a Fortress, and its Angles.

THE *Courtain*, see Chap. 4. under C.

The Flank, see Chap. 4. under F.

The Face, see Chap. 4. under F.

The Face prolonged, is the rest of the Flanking Line, after you have taken away the Face.

The Flank prolonged, is the prolonging of the Flank to the exterior Sides.

The Demi-Gorge, see Chap. 4. under D.

The Capital Line, see Chap. 4. under L.

The Line of Defence, is made high and razing, see Chap. 4. under L.

The Complement of the Courtain, see Ch. 4. under C.

The Distance of the Polygons, see Chap. 4. under D.

The half Distance of the Polygons, see Chap. 4. under D.

The interior Side of the Polygons, see Chap. 4. under C.

The exterior Side of the Polygons, see Chap. 4. under C.

The small Diameter, see Chap. 4. under P.

The great Diameter, see Chap. 4. under G.

See the Plan representing all these Parts.

F

Of

Of the Angles.

THE *Angle of the Center*, or *Angle of the Figure*, is that which is made by drawing right Lines from the Center to the two nearest Angles of the Polygon.

The *Angle of the Circumference* is the mixed Angle which is made by the Arch, which is drawn from one Gorge to the other.

The *Flanked Angle* is the Angle composed of two Faces.

The *Flanking Angle* is the Angle composed of the Line of Defence, and the Curtain.

The *Angle of Complement of the Line of Defence* is the Angle which is made of the two Complements, where they intersect one another.

The *Angle Form-Flank* is the Angle which is composed of one Flank and one Demi-Gorge.

The *Angle Form-Face* is that which is composed by one Flank and one Face.

The *Angle of the Moat* is that which is made before the Curtain where it cuts itself.

The *Re-entring Angle* is that which retires inward.

The *Saliant Angle* is that which advances toward the Field.

See the Plate A.

C H A P. III.

Of the Terms of the Measures.

A ROD is the Length of twelve geometrical Feet, and is made use of in Germany and Holland.

A Fathom

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A Fathom is the Length of six geometrical Feet, of which they make use in *France*.

A geometrical Pace is the Distance of five geometrical Feet.

The simple Pace is the Distance of three geometrical Feet.

The Cubit is the Length of one Foot and a half.

The geometrical Foot is the Distance of twelve Thumbs Breadth.

A Thumb's Breadth is the Length of twelve Lines, of which the one is a Barley-Corn's Distance from the other.

A German League is the Space of 4000 geometrical Paces.

An Italian League is the Space of 1000 geometrical Paces.

A simple French League is the Space of 1000 geometrical Paces.

A common League is the Space of 2000 geometrical Paces.

A Furlong is the Space of 125 geometrical Paces, of which they make use in *Greece*.

A Parasangue is the Distance of thirty Furlongs, or 3750 geometrical Paces, made use of in *Persia*.

The simple Schænus or Cord is the Distance of thirty Furlongs among the *Ægyptians*.

The Compound Schænus is the Distance of sixty Furlongs in *Ægypt*.



C H A P. IV.

Of the Names and Terms made use of as well in attacking, as in the Defence of Places, alphabetically set down.

A.

WINGS, are the large Sides which terminate and bound to the Right and Left the exterior Works, as the Horn and Crown-work, &c.

Wings of Armies, are the Regiments posted upon the right and left Hand, when the Army is drawn up in Battalia.

Antestature, is a small Retrenchment made of Gabions, to possess the Remainder of the grand Attack.

Approaches, are all Sorts of Advantages, by the Assistance of which we advance toward a Place besieged.

Arriere-Guard, is that Part of the Army which marches after the main Battle, to hinder and stop Deserters.

Arsenal, is a Place appointed for the forming and Preservation of every Thing that is necessary for Defence and Assault.

Artillery, is all Sort of Fire-Arms.

Assault, is an Attack made upon a Fortrefs, to win it by main Force.

Attack, is an Effort made by the Besiegers, to approach the Walls of a Fortrefs.

False Attack, is an Effort to the same End, but more remiss, to oblige the Besieged to divide their Forces.

To attack in Flank, is to attack both Sides of the Bastion.

Bacule,

B.

Bacule, is a Gate that is made like a Pit-Fall, with a Counterpoise, before the *Corps de Gards* advanced near the Gates, and which is supported by two great Stakes ; a Portcullis.

Banquette, a little Foot-Pace at the Bottom of the Parapet, upon which the Soldiers get up to fire into the Moat, or upon the Covert-way.

Barricadoes, are Trees cut with six Faces, crossed with Battoons as long as a Half-Pike, bound about with Iron at the Feet, and set up in Passages or Breaches to keep back as well the Horse as Foot.

Barriers, are great Stakes planted ten Feet one from another, about four or five Feet high, with their Transoms or overthwart Rafters, to stop those that would enter with Violence ; and where they cry to every Body that shew themselves, *Whence come ye ?*

Bastion, is a Heap of Earth usually raised upon the Angle of the Gorge, composed of two Flanks and two Faces.

Flat Bastion, is that which is raised upon the Courtain, when it is too long to be defended by the Bastions on each Side.

Battalion, are several Foot-Soldiers ranged in Battalia : It is composed of two Marches of Musqueteers, and a Center of Pike-men.

Battery, is a Place raised, whereon to plant the great Guns, and play upon the Enemy.

Berme, is a little Space of four or five Feet, left at the Foot of the Rampart without, to prevent the Earth from falling into the Moat.

Blinds, are Pieces of Wood set a-cross upon the Trenches to sustain the *Bavins* or Hurdles laden with Earth, which are to cover the Trench.

Red Bullets, are Bullets made red-hot in a Forge, with which the Canon are charged to set Fire upon Houses or Magazines.

Boyau, is a Moat bordered with a Parapet, which is drawn from one Trench to another for better Communication.

Breach, is the Ruin which the Cannon or a Mine makes in a Fortification to take it by Assault.

Brisure, is a Line from four to five Fathom, which is allowed to the Courtain and Orillon to make the hollow Tower, or to cover the concealed Flank.

C.

A Bomb-Chest, is a Kind of a Wooden Chest wherein are put from three to six Bombs, which is placed under Ground, to blow it up in the Air, in case it be taken.

Camp Flying, is a small Body of any Army which keeps the Field, to prevent the Incursions of the Enemy, harass the Country, hinder Convoys, and to throw itself into any besieged Place.

Caponiere, is a hollow Lodgment of about four or five Feet, bordered with a little Parapet of above two Feet high, to hold Planks laden with Earth; there are little Embrasures sometimes made in them, which are called *Murdresses*. This Lodgment is wide enough to contain twenty or thirty Soldiers, and is usually placed upon the Extremity of the Counterscarp.

Carcasse,

Carcasſe, is an artificial Fire, composed from three to four Granadoes, with ſeveral Barrels of Piſtolets charged, and wrapped up in Tow, dipped in oily Subſtances, with a pitched Cloth round about it: All which is put in a Kind of Lanthorn, which has a thin Plate of Iron at each End, held faſt by two Branches of Iron, which are croſſed by Circles of the ſame Matter; and in one of theſe thin Plates there is a Hole to fire the Carcasſe, which is afterwards forced into the Air like a Bomb.

Cartouche, is a Roll wherein the Charge of the Cannon is put, which, beſides the Powder, conſiſts of ſeveral Chain-Rings, ends of Piſtols, Bullets, Heads of Cart-Nails, and other Iron Materials: And the Cannon concealed in the retired Flanks is uſually charged with ſuch Cartouches to make the more Hayock.

Cafcons, are certain Wells, ſome more hollow than others, which are made in the Retrenchment of the Platform near the Wall, to give Air to a Mine.

Cafamatte, is a certain Vault made in a Part of the Flank which is next the Courtain, all of Maſons Work; it is made to fire upon the Enemy, and defend the Face of the oppoſite Baſtion and the Moat.

Cavalier, is a Maſs of Earth raiſed in a Fortreſs, to lodge the Cannon, to ſcour the Field, or oppoſe a commanding Work.

Chandeliers, are Wooden Parapets covered with Bavins, filled with Earth about a Foot high, made uſe of in Approaches, Mines and Galleries, to cover the Workmen, and hinder the Beſieged from conſtraining them to quit their Labour.

Chausés Trappes, or *Caltrops*, are Irons with four Spikes about four Inches long, so disposed, that which Way soever they fall, one Point still lies uppermost; they are made use of to throw into Moats and Breaches, to stop the hasty coming on of the Enemy.

Covert-Way, is a Walk round about the Moat towards the Country, having a Foot-Pace and the Glacis for a Parapet.

The Chemin de Ronde, is a Walk between the Rampart and the Wall.

The Skirt or *Chemise*, is the Solidity of the Wall from the Talus to the Stone Row.

Chevaux, or *Friesland Horses*, so called, because first made use of at *Groningen*, a City of *Friesland*, are great Pieces of Wood with six Sides, driven through Piles or Stakes of Wood armed with Iron, to hinder the Horse and Foot from going forward.

Circumvallation, is a Moat bordered with a Parapet, which flanks itself from Distance to Distance, sunk about the Besiegers Camp, as well to hinder the Relief of the Besieged, as to stop Deserters.

Clayes, are Twigs interwoven together, having the Figure of a long Square; they are placed upon an Allodgment, and covered with Earth; and sometimes they are laid upon marshy Ground to consolidate it.

Casser, is a hollowed Depth from six to seven Feet, and broad from sixteen to eighteen, all a-thwart a dry Moat: Upon the upper Part of this they place a Parapet, and a-cross Pieces of Wood, covered with Clay loaden with Earth.

Commandment, is a Height of nine Feet which one Place has above another.

Complement

Complement of the Courtain, is the Remainder of the Courtain after you have taken away its Flank, to the Angle of the Gorge.

Complement of the Line of Defence, is the Remainder of the Line of Defence, after you have taken away the Angle of the Flank.

Counter-Approaches, are Works which the Besieged make to hinder the Approaches of the Enemy.

Counter-scarp, is properly the declining of the Moat on that Side next the Country; although by this Term is understood, the Covert-way with its Parapet.

Counter-Forts, are certain Pillars and Parts of the Walls, distant from fifteen to twenty Feet one from another, which advance themselves as much as may be in the Ground, and join themselves to the Height of the Cordon by Vaults, to sustain the Chemin de Rondes, and part of the Rampart, to fortify the Wall, and strengthen the Ground.

Counter-Guards, are triangular Pieces, in Form of a large Parapet, which raise themselves above the Moat before the Faces and the Point of the Bastion to preserve them.

Countermine, is a subterranean Way which the Besieged make in search of the Enemy's Mine, to make away the Powder, and frustrate the effect of it, though fired by the Assailant.

Countervallation, is a Moat guarded with a Parapet, which the Besiegers make to secure themselves from the Sallies of the Garrison.

Corbeills, are a Sort of Gabions filled with Earth placed upon the Parapet to fire upon the Enemy, without being seen by them.

Cordon,

Cordon, is a Row of Stones made round, which is placed where the Wall ends, and the Parapet begins; and it runs round about the Place.

Coridor, is the Covert-way above the Counter-scarp, round about the Place, between the Moat and the Palisadoes.

Cornes or *Horns*, are Out-works which advance toward the Field, and carry in the Fore-part two half Bastions in the Form of Horns, which they present to the Enemy.

Crowning, is a Work drawn beyond the Horns to keep the Enemy at a Distance.

Courtain, is the longest streight Line that runs about the Rampart drawn from one Flank to the other, and bordered with a good Parapet five Feet high, behind which the Soldiers place themselves to fire upon the Covert-way, and into the Moat.

Cunete, a little Moat about four Fathom broad, which is usually sunk in the Middle of a great dry Moat, till you meet with Water. It is good to prevent the Besiegers Mining.

D.

Defenses, are all Sorts of Works that flank one another, and which the Enemy desires to ruin, before he strives to pass the Moat.

Defile, is a streight narrow Passage, through which there is no marching but in File.

Debors, are all Sorts of separate Out-works, as Ravelins, Half-Moons, Hornworks, Crownworks, Counterguards, Tenailles, &c. the better to secure the main Place.

Demi-distance of Polygons, is the Distance between the exterior Polygons and the Flanks.

Demi-Gorge, is a Line drawn from the Flank to the Angle of the Polygon.

Demi-

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Demi-lune, is a small flanked Bastion, placed before the Point of a Bastion, when it is too weak; sometimes this Work is placed before the Curtain, when the Moat is a little wider than it ought to be.

Descent into the Moat, is a deep digging into the Earth of the Cover-way, in Form of a Trench, of which the upper Part is covered against artificial Fires, to secure the Descent into the Moat.

Distance of Polygons, is the Line composed from the Flank and its Prolongation, to the exterior Polygon.

Donjon, is a Place of Retreat, to capitulate with more Advantage in case of Necessity.

E.

Embrasure, the Hole through which the great Guns are discharged.

Embuscade, the Place where the Soldiers hide themselves to surprize the Enemy.

Enceinte, the Circumference of a Place, sometimes lined, and composed of Bastions and Curtains, sometimes not.

Esplanade, is the Place void of Houses, between the Citadel and the Town.

F.

Face, is the most advanced Part of the Bastion toward the Field, and is the first attacked.

Fascins, are Bavins of small Wood, two Feet broad, and four long, bound about at the Ends and Middle, thrown into Moats where there is much Water, to facilitate the Passage over to the Wall.

Fals

Fals Braye, is a small Rampart four Fathom wide, bordered with a Parapet, and a banquet, running round about the Body of the Place. It is made use of to fire upon the Enemy, when he is already so far advanced, that you cannot force him back from off the Parapet of the Body of the Place; or else, to receive the Ruins which the Cannon make in the Body of the Place.

Flank, is the Part which joins the Courtain to the Face of the Bastion, from which the Face of the next Bastion requires its Defence.

Flank Covert, is that, the exterior Part of which advances to secure the innermost; which advanced Part, if it be rounded, is called an *Orillon*.

Flank Fichant, is that which plays, and fixes its Bullets in a direct Line in the Face of the adjoining Bastion.

Flank Razant, is that, from the Conjunction of which with the Courtain, the Shot razes the Face of the next Bastion; which happens when the Face cannot be discovered but from the Flank alone.

To Flank a Place, is to play upon a Place in such a Manner, that there shall be no Part of it but what is defended; and from which you may play upon the Enemy both in Front and Rear, and so oblige him to retire.

Forts of the Field, or *Fortins*, are all Fortresses, whose flanked Angles are distant one from another 120 Fathom. They are only for a Time to guard some Passage, or dangerous Place; or else they are used in Circumvallation.

Foudage, is a small Mine made under the Ground, which the Enemy would blow up. It is furnished with some Sacks of Powder, to which the Saw-
cedge

cedge is fixed, which answers to another Post, to the end it may be fired without Danger.

Fraises, are Pieces of Wood from seven to eight Feet long, driven in almost half Way into the Earth of the Rampart without Side, and a little below the Parapet, they present their Points somewhat sloping toward the Field ; and are made use of to prevent Deserters and Surprizes.

G.

Gabions, are Baskets equally wide at Top and Bottom, about four Feet in Diameter ; they are filled with Earth, and usually placed upon Batteries and Parapets that have suffered very much, and before other Places, to secure them from the Enemy's Shot.

Gallery, is a covered Walk, either of Earth or Turf. The Sides of it are made with Planks and Pillars ; and they are made use of in the Moat already filled with Faggots and Bavins, to the end the Miner may approach safe to the Bastion.

Glacis, is the Parapet of the Covert-way which loses itself insensibly in the Field. The largest are the best.

Gorge, is the Entrance of the Platform of the Bastions and other Works : It never ought to have a Parapet, for fear the Enemy being Master of it, he should secure himself thereby from the Shot of the Garrison.

Granado, a little hollow Globe filled with Powder, to which there answers a little Fusée of Powder, to set them on Fire ; they are used to fire close and narrow Places ; or else to disorder the Ranks of the Soldiers.

Grand Demi-Diameter, is the Line composed of the Capital, and the small Demi-Diameter of the Polygon.

Grazons, are Pieces of fresh Earth, covered with Grass, about a Foot long, and half a Foot thick, cut in the Form of a Wedge to line the Parapet, and the Traverses of the Galleries.

H.

Herisson, a Beam, with a great Quantity of Nails having their Points outward ; it is supported by a Pivot upon which it turns, to stop up any Passage instead of a Barrier.

Herse, is a Lattice, or Portcullis, of great Pieces of sharp-pointed Wood at the lower End, sustained by a Cord fastened to a *Moulinet*, which is cut in case of Surprize, to the End the Herse may fall, and stop up the Passage of a Gate, or other Entrance of a Fortres.

Horse-Shoe, is a Work somewhat round, somewhat oval, bordered with a Parapet : It is made to secure a Gate, or to relieve an over-tedious Defence.

L.

Line Capital, is a Line drawn from the Angle of the Gorge to the Angle of the Bastion.

Line Cogital, is the Line drawn from the Angle of the Center to the Angle of the Bastion.

Line of Defence, is that which is represented by the Discharge of the small Shot, which uncovers the Face of one Bastion by razing it.

Line of Defence Fichant, is the Line drawn from the common Point to the Curtain, and from the Flank to the flanked Angle of the Bastion.

Line

Line of Defence Razant, is the Line drawn from the capital Line of a Bastion, to that Part of the Courtain where the Defence begins, to discover the Face of the same Bastion.

Line of Communication, are the Lines that run from one Work to another, to stop the Fury of the Enemy.

Lines within-side, are the Moats toward the Place to hinder Sallies.

Lines without-side, are the Moats toward the Field to hinder Relief.

Lodgment of an Attack, is a Work cast up in a dangerous Post, to secure themselves against the Enemy's Fire: This Lodgment is made of all the Materials that are capable to make Resistance.

To Line, is nothing else but to environ a Rampart, Parapet or Moat, with a good Wall or good Turf.

M.

Madrier, is a thick Plank, sufficient to cover the Mouth of a Petard, and which is applied with the Petard against the Places they would break: This Term is also applied to several flat Beams which are put at the Bottom of a Moat to support the Wall.

Mantellet, is one or several Planks joined together, and covered with Tin, carried upon two Wheels, which the Pioneers in a Siege drive before them to secure themselves against the small Shot.

Merlon, is that Part of the Parapet which is between the two Embrasures.

Mortier, is a Piece of great Cannon very short, which is charged with Bombs, Carcasses, or Stones; and is mounted upon a Carriage, the Wheels of which are very low.

Moulinet, is a Cross of Wood, which turns horizontally upon a wooden Stake, which stands at the Side of the *Barrier*, between the Bars of which the Footmen pass.

Moyenau, a Sort of small flat Bastions, placed in the Middle of an over long Courtain, of which the Bastions that are at the Extremities, are not well defended from the small Shot by reason of their Distance. This Work is proper for the placing in it a Body of Musketeers, to fire from all Sides.

N.

Nailing of Cannon, the driving of a Nail by Force into the Touch-hole of a great Gun.

O.

Orgues, are thick and long Pieces of Wood, hung up over a Gate, every one by a Cord, which answers to the *Moulinet*, that is to be cut in case of a Surprise; and they are to be preferred before *Herses*.

Orillon, is a small Rounding, which joining with the hollow Tower, at the End of the Face of the Bastion, covers one Part of the Flank.

P.

Palisadoes, are wooden Stakes from five to seven Feet high, armed with two or three Iron Points, which are fixed before Fortresses, Courtains, Ramparts, and Glaces: Some there are which are not armed with Iron.

Parapet, is an Elevation of Earth upon the Rampart, behind which the Soldiers stand, and where the Canon is planted for the Defence of the Place.

Park,

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Park, is a certain Place made choice of in the Camp, out of Cannon-shot of the Place besieged, to plant the Artillery, and to keep the artificial Fires, Powder, and warlike Ammunition; which is only guarded by Pike-men.

Petard, is a hollow Engine made of Metal, almost in the Shape of a Cap, from seven to eight Inches deep, and five Diameter in the Muzzle. It is charged with Powder beaten as small as may be, and then fixed to the *Madrier*.

Petty Demi-Diameter, is the Circumference drawn from the Center through the Gorges.

Place of Arms, is a Piece of Ground sufficient to draw up the Men to be sent from thence as Occasion requires.

Place of Arms without, is a Place allowed to the Covert-ways where they make obtuse Angles, whereon to plant some Pieces of Cannon, or Falcons, to force those that advance in their Approaches to retire.

Place of Arms particular, is a Place near every Bastion, whence the Soldiers sent from the grand Place to the Quarters assigned them, relieve those that are either upon the Guard, or in Fight.

Place irregular, is a Place whose Angles and Sides are unequal.

Place regular, whose Angles and Sides are every where equal.

Plane, the Representation of a Work in its Height and Breadth.

Platform, is the whole Piece of Fortification raised in a re-entring Angle.

Polygon exterior, is the Distance of one Point of a Bastion from the Point of the other.

Pont de Jong, is a Bridge made of great Bundles of Bullrushes, that grow in the Marshes, which are afterwards bound together, upon which they lay Planks, and then lay them in muddy and marshy Places to secure their footing.

Pont Flottant, or Floating Bridge, is a Bridge made in Form of a Redoubt composed of two Boats covered with Planks: They ought to be so solidly framed, as to bear Horse and Cannon.

Postern, is a false Door, often made at the Bottom of the Courtain, or near the Orillon, for private Sallies.

Profil, the Draught of a Work, with all its Lengths, Breadths and Heights.

Q.

Quarter of a Siege, is the Incampment upon one of the most principal and important Passages round about the Place besieged, to prevent Relief, and Convoys.

R.

Rawelin, is a small triangular Work without Flanks, and having no more than its two Faces: It is generally raised before the Courtains, where the Moat makes a saliant Angle.

Redans, Works made in Form of the Teeth of a Saw in re-entring and saliant Angles, to the End that one Part may defend another: They are usually placed upon the Entrances into Rivers.

Redoubt, is a small square Foot, having no Defence but in Front. It is usually designed to maintain the Trench, for Circumvallations and Countervallations; and in watry Places they are often made of Masons Work for the Security of the Neighbourhood.

Reduit,

Reduit, an advantageous Piece of Ground entrenched from the rest of the Place, to retire to in case of Surprise.

Rampart, is the raising of the Earth which runs about a Place, composed of Bastions and Courts, wherein to put the Soldiers, and plant the Cannon for the Defence of the Place.

Retirade, an Intrenchment formed by two Parapets making a re-entring Angle, which is made in a Work resolved to be disputed Inch by Inch. Sometimes it has a Moat.

Retrenchment, is a Work made of part of a Rampart, when the Enemy is so far advanced, that he is no longer to be resisted or beaten from the old Rampart; and to the End that he may not make any new Opposition; it is bordered with a good Parapet, and sometimes with Gabions and Bavins laden with Earth.

Rideau, is a small Elevation of Earth in the plain Field, which extends itself in Length; very proper for those that would besiege a Place at a near Distance, and to secure those that would approach to the Foot of the Place.

Rondel, is a round Tower sometimes raised at the Foot of the Bastions.

S.

Sack of Earth, a Sack of coarse Cloth to contain a Foot, or a Foot and a half; serviceable upon several Occasions, but especially for the making Retrenchments in haste.

The Saignor, a Moat, to empty the Water by subterranean Conveyances, to pass it the more easily, after you have cast Hurdles upon the Mud that remains.

G 2

Sappe,

Sappe, is the deep digging into the Earth of the Covert-way and Glacis in the Form of a Trench. The Earth which is thence digged out, serves for Security on the Right and Left, and covers you above against the Fire-works by the help of the Hurdles laden with Earth.

A Sarrafin, is no more than a Herse.

Saucidge, is a Piece of long Cloth, of which they sow the Sides all along in Form of a Gut, which they dip in Pitch, and fill with Powder: The Largeness of it ought to be so much as to contain a Tennis-Ball; and then they put one End of it to the Place where the Mine is, or a Foudage, or Chest of Bombs, and the other End answers to the Place where the Engineer stands that sets it on fire.

Saucidges, are Faggots made of great Boughs, bound in the Middle and both Ends; whose use is the same with that of Bavins.

Shouldring, is nothing but the Orillon.

Scalade, the mounting of the Wall with Ladders, *Scarp*, the *Talas*.

Star, a Work with several Faces, composed of Parts, of which the one flanks the other.

Sillon or *Envelop*, a little Rampart covered with its Parapet, raised in a very large Moat, the Draught of which forms re-entring and saliant Angles, to the end that the Parts may reciprocally flank each other.

T.

Talut, is that Declivity or Inclination which is allowed to Works whether of Earth or Masonry, the better to support them; and the worse the Earth is, the more sloping they ought to be.

I

Tenaille,

Tenaille, is a Fortification that has in Front a re-entring Angle, when it has no Flanks ; and this is called a simple *Tenaille* ; But if it have Flanks, then it is called a flanked *Tenaille*.

Terre-plain, is that part of the Rampart which is equally level for the Recoil of the Cannon.

Towre Hollow, is a Rounding made of the Remainder of the two Brisures to join the Courtain to the Orillon ; where the small Shot are placed, that they may not be so much exposed to the View of the Enemy.

Trenches, are Moats which the Besiegers make to approach the more securely to the Place attacked. The Depth of it ought to be from six to seven Feet ; the Breadth from eight to ten. They are so to be carried on, as not to be in View of the Enemy.

Traverse, is a little Moat bordered with a Parapet to the Right and Left, which the Besieger makes quite athwart the Moat of the Place, to pass secure from Flank Shot, and bring his Miners to the Bastion. This Traverse is covered with Hurdles loaden with Earth, for Security from the Fire-works. The only Difference between this Work and the Coffin, is this, that the one is made by the Besieger, and the other by the Besieged.

V.

Vedette, a Centinel on Horseback.

B O O K II.

C H A P. I.

Of the Maxims of Fortification.

SINCE it is impossible to build a Fortress, without having considered before-hand what Reasons there are to induce an Engineer to do it after such a Manner, that there is no great Matter to be objected against it; there are some certain Maxims established, according to which, when a Fortification is raised, there can be but little said against its Advantages to those that are within; as you may easily examine it yourself by the following Observations.

I. All the Parts which are to enclose a Space of Ground, ought to be flanked; that is to say, viewed on every Side, that so there may be no Shelter about the Place where the Enemy may lodge himself, but what may be discovered by those within, not only from the Front, but from the Sides, and even from behind, if it be possible.

II. Whatsoever encloses a durable Fortification, must be either Flank, Face, or Courtain, and built after such a Manner, that the first Discharges of the Cannon may not be able to pierce its Thickness.

III. Regular

III. Regular Fortification is much to be preferred before that which is irregular.

IV. It is impossible to fortify a Triangle after the regular Way, because the Angle of the Gorge is always less than ninety Degrees.

V. The acuter the Angle of the Center is, the Place is by so much the stronger, and consequently better, because it will have more Sides.

VI. The Angle of the Bastion must never be greater than 100 Degrees, nor less than sixty; for being bigger, the Face cannot be defended as it ought to be; and being less, it is not able to resist the Injury of the Weather, or the Efforts of the Mines and Cannon. See Chap. 1. Sect. 4. of Book IV.

VII. The greatest Angles are best to fortify.

VIII. The Angle of the Courtain ought never to be less than ninety Degrees, nor greater than 110; because, if it be larger, it is too much subject to the View of the Enemy. See Chap. 1. Sect. 5. of Book IV.

IX. The great Demi-Gorges are to be preferred before the small ones, as well because there is more Space to retrench in, as because one may make retiring Flanks, which adds very much to the Strength of the Place.

X. Great Flanks are best.

XI. The Face ought to be never less than the half of the Courtain, if it be not in an irregular Fortification.

XII. The Faces of the Bastion ought to be defended by the small Shot of the opposite Flanks.

XIII. The shortest Faces are best, because they are not so subject to be attacked, as when they come out a great way in the Country. See Chap. 3. of Book IV.

XIV. The Courtain ought never to be shorter than sixty Fathoms, which is 360 Feet *English*; nor longer than 100; if it be not in an irregular Fortification.

XV. The Line of Defence must not be of greater Length than 120 or 125 Fathoms, because a Musquet can carry no farther to do Execution. *Holdman* contradicts to this Axiom, when he says, that it may be 150 Fathoms; and likewise *George Pascha*, who believes it may be 136 Fathoms long.

XVI. The Talut or Level ought by no means to be forced or streightened, but ought to have sloap enough, that the Ground or Earth may settle of itself.

XVII. Large and deep Trenches are to be preferred before those that are narrow and hollow, or large and less deep, because the Enemy will find more Difficulty to get over the first Sort. See Chap. 10. of Book I.

XVIII. Dry

XVIII. Dry Trenches are to be esteemed before those that are full of Water, especially in great Places, where Sallies, Retreats, and Succours, are necessary.

XIX. Trenches full of Water that cannot easily be drained, ought to be preferred before those that are dry in small Fortresses, where Sallies, Retreats, and Succours, are not so necessary.

XX. The Out-works ought always to be lower than the Body of the Place ; and those that are at the greatest Distance ought to be the lowest.

CHAP. II.

Of the Situation of Places.

AS it is very rarely permitted to make choice of that Space of Ground which is to be fortified ; but on the contrary, the Place is almost always determined, whether we design to repair an old Fortification, or surround any Town with Bastions, and other kind of Works ; or whether we are to make ourselves Masters of the Passage of a River, or any strait Place, or an Eminence, that is of Advantage to command the flat Country, or an Island in a River, or of one or more Jettings out of Land into the Sea for the making a Port ; and lastly, for several other Uses, the recital whereof would be too tedious : It is necessary upon these Accounts to understand, what Kind of Situations are best for the erecting a strong

strong Hold, and to know the Opinions of others concerning this Matter.

I. What are the Advantages of a Fortrefs situated upon a Mountain.

1. This Fortification is not easily ruined by Mines.

2. The Enemy will be at a great deal of Difficulty to bring their Machines to batter down this Fortification.

3. Those of the Place may discover the Enemy at a great Distance, and so hinder them from making their Approaches nearer.

4. The Horse or Batteries of the Enemy, which are planted either on plain or rising Ground, can no Ways do any Damage to this Fortification, it being always lower.

5. Upon an Eminence, the Air is always more healthy than in Vallies or lower Places.

6. The Enemy will but very rarely be able to take such a Place by Assault.

What are the Disadvantages of a Fortrefs built upon a Rock.

1. They commonly want Water in such a Place.

2. It is difficult to bring thither Materials, Provisions, and other Ammunition.

3. These Fortifications are, for the most part, not very durable, having only a sandy or gravelly Earth for Foundation.

4. Places so situated, are not to be succoured but with great Difficulty.

5. Such

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5. Such a Place cannot be well defended, because what is done by the Cannon from Top to Bottom, is but of little Consequence.

6. Sallies are there very dangerous, especially if they be at any Distance from the Counterscarps.

7. These Fortifications are almost always irregular.

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It is to be observed, That these kind of Situations are good for Citadels, Castles, and other small Forts, in order to command the Country thereabouts.

II. The Advantages of a marshy or fenny Situation.

1. The Enemy cannot come near it without Danger of being lost.

2. This Fortification is not easily blown up.

3. These Places may be fortified for little Charge.

4. They have there no need of a great Garrison.

The Disadvantages of a marshy Situation.

1. It is almost impossible to relieve it.

2. It must be strengthened with Piles driven in.

3. Sallies thence are commonly unsuccessful.

4. The Air is there always unhealthy, which is the Occasion of frequent Distempers, because the Water there is always corrupted.

5. These Places may be attacked without any great Loss of Men, provided they stay till the Frosts.

III. The Advantages of a Place encompassed round with Water.

1. It cannot be undermined.

2. There

2. There is no Occasion for any great Works.
3. The Enemy cannot always discharge their Cannon with any Certainty, because the Water abates much of their Force.
4. The Besieged may very easily set fire to the Enemy's Shipping.
5. The Naval Army is too much exposed to the View of the Artillery of the Place.

The Disadvantages of a Place surrounded with Water.

1. The Enemy may easily stop their Provision, and hinder their Succours.
2. Boats alone are sufficient to attack such a Place, and so there is no Occasion for Horse.
3. These Places are more subject to Diseases than others.

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We may affirm, that these Places that are encompassed all around with Water, which cannot be quite drained, or at least with great Difficulty, are the best notwithstanding, because they are, as it were, fortified by Nature.

IV. The Advantages of Places situated upon an open plain Ground.

1. There is great Plenty of good Earth.
2. They are never there in want of Water.
3. Almost all these Places are commonly regular.
4. They have there Earth enough to make Retrenchments, in case the Enemy make their Attacks with great Fury.

5. The

5. The Enemy had need to have two or three Armies, if they would intercept the Provision and Ammunition coming to those of the Place from all Parts.

The Disadvantages of Places erected upon a plain Ground.

1. The good Soil that there is about such a Place, serves only for the Enemy to make Retrenchments, Batteries, Approaches, Redoubts, and other Works, from thence they may do great Damage to the Besieged.

2. The Enemy may form their Camp, as those of the Place did their Fortification; that is to say, they may give it a regular Figure, and encompass it with a good Trench, and a good Rampart.

3. The Ground is very good to make Mines under such a Place.

4. The Enemy may seize all the Fruits growing about these Places.

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These Places however are best, because those of the Place will take double the Advantage that the Enemy can have.

V. The Side of a Mountain is a very ill Place to fortify, and it must be avoided as much as may be, because the Top of the Mountain almost always commands the Place within.

VI. The Valley is no good Place to fortify, because the Enemy may discover them from the Top of the Mountain.

VII. *The*

VII. The Advantages of Places situated on the Sides of any great River.

1. You may bring thither by Water, whatsoever is necessary for Building, and for the Soldiers.
2. You may fortify the Circumference after the regular Manner, or at least very near it : The Side towards the Water is fortified with small Charge.
3. It may be easily relieved.
4. Earth is there very plentiful for repairing the Works, and for making Retrenchments.
5. You may there make Sluices to put all the Country thereabouts under Water.
6. They never want there any Water.
7. The Enemy must have a great many Troops to lay Siege to such a Place, by reason of the Distance of the Quarters.
8. If it be attacked only by Land, nothing hinders but that the Besieged may pass the River at Pleasure, and receive Succours by Boats.
9. If it be attacked both by Land and by Water, there must be two great Armies, which will be very chargeable.

The Disadvantages of Places situated on the Sides of a great River.

1. The River serves the Enemy for transporting whatsoever is necessary for a Siege.
2. The Enemy may cast up great Heaps of Earth to command the Place.
3. The Enemy may easily shelter themselves from the Firing of the Besieged, having great Plenty of Earth.

A D V E R.

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It is not to be denied, but that these Places are to be preferred before any of those that we have now mentioned, in case they are Masters of the Pass, by which the Provision and Ammunition is to come in.

C H A P. III.

Of the Quality of the Earth.

WHEN you have once made choice of a Place for the erecting a Fortress, before you engage yourself in so expensive an Undertaking, you must examine the Quality of the Earth, and consider whether it be good or bad: For there are very advantageous Situations, the Earth whereof is good for nothing; and on the contrary, there are ill Situations that have a very good Soil, but they lie subject to be commanded after such a Rate, that it would be great Folly to settle there: As may be evident by the following Observations.

Sett. I. Mountains commonly have a stony Ground, which is the worst of all, as well because it will not stick together, as because the Parapets made thereof are good for nothing: But if you are compelled to fortify in such a Place, you must make choice of the best Veins of Earth to make the Parapet, and cause it to be brought from elsewhere. It is true, this sort of Earth is of some Advantage,

Advantage, in that the Besiegers will find it difficult to cover themselves in their Approaches for want of good Earth.

Seet. 2. Gravelly or sandy Earth is likewise very bad, by reason that it wants a binding Quality, being always apt to tumble down; when you are forced to make use of this, you must mix some good Earth therewith, or some old Dung, and the Ramparts must be well lined with Stones or Bricks, and the Parapets with Turfs.

Seet. 3. Marshy Ground is better than the two former Sorts, although generally it is not very good, because when it comes to dry, being raised into Ramparts and Parapets, it is subject to fall to Pieces; besides, it is difficult to find Earth enough about a marshy Place for raising of Ramparts, Parapets, and Glacis's, of a reasonable Height; and moreover, the Foundation of these Works must be always strengthened with Piles. But if there be a Necessity of raising Fortifications in these Places, it must be during the Heats, that so the Earth may have the greater Consistence.

Seet. 4. The best kind of Earth for fortifying, is that which they call fat or fertile Ground, because it is pliable; and you are not obliged to strengthen the Foundation with Piles, nor to line the Ramparts, unless you will.

C H A P. IV.

Of Provision, and other Necessaries.

SEEING a Place cannot be able to endure a long Siege, if it has not wherewithal to make Resistance, therefore there must be Provision made of whatsoever is necessary for a Soldier; under which Head is to be understood, Money to pay the Troops, Meal, Corn, Hay, Wine, Beer, Brandy, Butter, Salt, Wood, Powder, Lead, Match, Bullets, Cannon or great Guns, Muskets, Pikes, Sulphur, Pitch, Brimstone, Palisades, *Chevaux de Frise*, Hand-Mills, Horse-Mills, and Wind-Mills, that so, if the Enemy should cut off the Water, they might not be without something to grind their Corn. A good Commander will take Care of all this. An able Physician, Chirurgeon, and Apothecary, are there likewise very necessary. To these there might be added, some other Things requisite, in order to keep the Soldiers in good Heart.



BOOK III.

CHAP. I.

Sect. 1. *How to inscribe any Polygon within a Circle given.*

THIS Problem is commonly treated of in *Geometry*; nevertheless, because it is impossible to work on a regular Fortification on Paper, without knowing before-hand how to inscribe regular Figures in a Circle given or taken at Pleasure, we shall at present discourse something thereof.

1. Divide the Diameter of your Circle given, A B, into as many equal Parts as you would give Sides to your Figure: For Example, into five.

2. Draw the Diameter A B, and make with this Distance of Points A B, two Arches to intersect in C.

3. Draw from the Point C, through the second Part which is marked by the Point E, of the said Diameter, a right Line, till it touch the Circumference also below the Diameter in H.

4. This Distance from the Intersection to the first Point A, of the Diameter, will be always one Side of the Polygon demanded.

See the Plate B, Fig. 2.

Sect. 2.

Sect. 2. *How to make a Scale.*

As every Thing is to be done by a Scale, you must know likewise the Manner how it is made ; which is as follows :

1. Divide a Line into ten equal Parts, and one of these, to shew the Feet, into ten others ; so one of these last ten will make the hundredth Part of your Line ; that is to say, one Fathom of your Scale.

2. To make the Scale well, you must divide also one Fathom into six other equal Parts, to shew the Feet ; for a Fathom is six geometrical Feet, as have been already said. And by this Manner you will have a perfect Scale, for to know all the Breadths, Lengths and Heights.

3. When you would make any Thing that should be very exact, you must likewise take a Foot, and divide it into twelve other equal Parts, and so you will have the Inches ; for a Foot contains twelve Inches.

C H A P. II.

How to design a Square.

IN *France* there are three sorts of Fortifications, the large, the middle-sized, and the small ; but at present they never make use but of the middle-sized : Nevertheless we will first shew the Difference, before we speak of the middle-sized.

*The Square.**The large Manner.*

	<i>Fathoms</i>	<i>Feet</i>
1. The Semi-Diameter	141	00
2. The Side or exterior Polygon	200	00
3. The Perpendicular	27	00
4. The Face	60	00
5. For the Complement of the Line of Defence take	38	00
6. The Flank	22	00
7. The Courtain	73	04
8. The Line of Defence	141	04

The middle-sized.

1. The Semi-Diameter	127	02
2. The exterior Side	180	00
3. The Perpendicular	22	00
4. The Face	55	00
5. For the Complement of the Line of Defence take	33	00
6. The Flank	18	01
7. The Courtain	64	04
8. The Line of Defence	126	00

The small.

1. The Semi-Diameter	113	01
2. The exterior Side	160	00
3. The Perpendicular	21	00
4. The Face	45	00
5. For the Complement of the Line of Defence take	33	00
6. The Flank	18	04
7. The Courtain	64	00
8. The Line of Defence.	115	04

The

The Explanation of the middle-sized Table.

Having seen the Difference between these three Manners, we shall only speak of the middle-sized, as being the most in use at this Day; and to begin, we will examine the said middle-sized Table.

1. Take 127 Fathoms, and two Feet between the Points of the Compass, and make a Circle.

2. Take 180 Fathoms, and divide them with the Circle into four equal Parts: When they are joined the one to the other, they are called exterior Sides or Polygons, as A, B, C, D.

3. Divide one of these four Sides into two equal Parts with ninety Fathoms, as E, F, G, H.

4. Draw from the Points, E, F, G, H, streight Lines toward the Center, which are called Perpendiculars; to which must be allowed twenty-two Fathoms in Length, as I, L, M, N.

5. Set the Rule to the capital Points, A, B, C, D, and draw streight Lines through the End of the Perpendiculars I, L, M, N, at Pleasure.

6. Take fifty-five Fathoms, and place them upon the Lines drawn from the capital Points, to mark out the Length of the Faces, as a, b, c, d, e, f, g.

7. Take thirty-five Fathoms, and put them from the Point where the Perpendicular ends, viz. from the Point I, L, M, N, upon the Lines that have gone beyond the said Points, to mark out the Length that is to be taken for the Complement of the Line of Defence, as JO, JP, LQ, LR, MS, MT, NV, NX.

8. Draw the end of the Faces and these Points OPQRSTVX, which terminate the Complement of the Defence, and you will have the Flanks.

H 3

9. Then

9. Then join together the Feet of the Flanks, and you will have the Courtains.

To make the Orillon.

Monfieur de Vauban does not leave his Flanks, as Monfieur Pagan has done, or as the Dutch and Germans do at this Day; but he conceals one Part, the better to cover the Cannon by means of the Orillon: And for that Reason we will shew you his Manner of raising it, which is not very difficult.

1. Divide the Flank into three equal Parts.

2. Divide the first of the three into two other equal Parts, to join from this Middle, the two Extremities of the first Part, on the Side of the Moat; and this little Rounding makes the Orillon.

To make the hollow Tower or Plank retired.

As you have seen the reforming of the first of the three Parts, placed upon the Flank, now you shall see another of the two remaining Parts, the Form of which you must henceforward call the *Hollow Tower*, the Construction of which is thus:

1. Draw from the capital Points of the Bastions, a small streight Line within side of the Bastion, through the End of the Orillon.

2. Put five Fathoms upon this Line which you have drawn, as also upon that which is almost parallel to the lower Part of the Courtain. This is called the *Brisure*,

3. Take the Extremities of the Brisure with the Compass, and with that Distance draw two Arches, which intersect one another toward the Moat, in Figure 8,

4

4. Put

*X 17 p. 102
into three p. 102
it is 50
it is also a
line now
then 2 1/2.*

4. Put the Compass upon that Interfection, and join the said Extremities of the Brisure together by a crooked Line; and thus you will have the Figure which is made at this Day in *France* instead of the Flanks, as also the Design of the entire Square. See under B, Fig. 3.

C H A P. III.

Of the Structure of the Body of the Place of the Square.

WE are now to see what Largeness or Breadth is to be allowed to the Ramparts, Parapets, Moats, Covert-Ways, and Glacis's of Squares, and after what Manner they are to be drawn: Observe then what follows.

	Fathoms	Feet
1. The Base of the Rampart	11	00
2. The Base of the Parapet	03	00
3. The first Banquet	00	01 $\frac{1}{2}$
4. The second Banquet	00	02
5. The Moat from 16 to	20	00
6. The Covert-Way	04	00
7. The Place of Arms	13	00
8. The Glacis	36	00

In case the Ground will give you leave to take more, you may do it.

The Explanation of this Table.

1. Take eleven Fathoms, and carry them parallel to the Courtains, Flanks, Faces, Brisures, and hollow Towers, on that Side toward the inside of the Place, to know after what Manner you

are to draw the Parallel to the hollow Tower: Put these eleven Fathoms before; then open your Compasses to the Point from whence you drew your hollow Tower, and draw from the same Point through the said eleven Fathoms a crooked Line, till it joins the Basis of the Brisure and the Face.

2. Take three Fathoms, and carry them in the same Manner parallel to the Design, to the end the Basis of the Rampart may be opposite to it, and parallel. But you ought to make this Parapet, or three Fathoms, parallel also to the Orillon, as far as the Brisure: For there it is, that the Parapet of the Orillon ought to end. As for the hollow Towers, put as already has been said, three Fathoms, for that is the Breadth of the Parapet, before the hollow Tower, and open the Compass to the Point from which you drew the hollow Tower, and the Base of its Rampart, to draw from the same Point through the three Fathoms put before the hollow Tower a crooked Line joining the Parapet of the lower Brisure, and the Prolongation of the upper Brisure together; and there, where I touch the said Prolongation, from thence I draw a small Line to the next Brisure.

3. Take a Foot and a half, and draw with that Distance a Parallel round about the Parapet, toward the Base of the Rampart, which will represent to you the first Banquet; round about which you must draw another Parallel of two Feet to mark out the second.

4. To draw the Breadth of the Moat, take from sixteen to twenty Fathoms, and draw with that Distance a Parallel to the Faces, till they intersect

one

one another before the Curtain. To draw this Parallel round about the Point of the Bastion, you must put the Compass of the Overture from sixteen to twenty Fathoms upon the said Point of the Bastion, and draw a little Rounding from thence to the Parallels of the Faces.

5. To mark out the Covert-way, take from four to five Fathoms, and carry a Parallel to the Moat; but set it from a Point before the Rounding.

5. Where the Covert-way makes a salient Angle, for Example in G, put there ten Fathoms to each Side, as G, J, and G, H, and afterwards with fifteen Fathoms you shall make Points where the ten Fathoms terminate, and draw from the said Points, in the Point of the Intersection, straight Lines; and this is that which is called the Place of Arms.

7. Take thirty-six Fathoms, or as much as the Ground will permit, and bring a Parallel round about the Covert-way, and the Place of Arms to mark out the Glacis or Parapet of the Covert-way. And thus your Square will be perfectly finished.

C H A P. IV.

Of the Structure of the Half-Moon before the Curtain of the Square.

FROM the Angle of the Moat, or Counter-scarp, raise a Perpendicular as long as the Demi-Curtain, with its Brisure for the capital P, Q. Observe that in Polygons the Capital ought to be forty-five Fathoms in Length,

2. From

2. From the Point Q draw a streight Line toward the Orillon of the Bastion, terminating on the Side of the Moat in S and D.

3. Take five Fathoms, and put them from S and D, upon the Counterfcarp, toward the inside of the Half-Moon, as E F.

4. Put the Rule perpendicularly upon the Curtain of the Body of the Place, and erect from the Points E F, two small streight Lines, till they cut the Faces of the Half-Moon, as in V H, and the Lines E V, F H, will make you the Flanks of the Half-Moon.

5. Draw the Base of the Rampart A B, of eight Fathoms, parallel to the Faces, and the Flanks of the Half-Moon toward the inside, as also the Parapet A C, of three Fathoms, the first Banquet of one Foot and a half, the second of two Feet.

6. Take twelve Fathoms for the Wideness of the Moat, which ought to be drawn parallel to the Faces, but not to the Flanks: You must give it also its rounding before the capital Point.

7. The Covert-way, Place of Arms, and Glacis, are made as in Chap. 3. L. 3. Sect 5, 6. 7. See the Plate C.

C H A P. V.

Of the Structure of the Ravelin before the Curtain.

THIS Work is done as the Half-Moon, when you allow it no Flanks.

Sect. 2.

Sect. 2. *To make a Ravelin with Lunettes.*

Having raised the Ravelin as it ought to be done,

1. Take two Parts of the Flank of the Body of the Place, and put them at the Angle of the two Moats; that is, from the Moat of the Body of the Place and that of the Ravelin, upon the Counterscarp, to mark out the Demi-Gorges of the Lunettes, as A B, and A C.

2. Take the Flank of the Body of the Place entire, and draw from the Point B C, two Arches to cut one another in D, and then join B D, and C D, together by a streight Line, to have the Faces of the Lunettes.

3. You draw the Moat of these Lunettes from the half of that of the Body of the Place, allowing it also a Rounding.

4. The Base of the Rampart, the Parapets, and the Banquets, is made as for the Ravelin. See the Plate D, Fig. V.

Sect. 3. *To make a Ravelin with Counter-guards.*

Having made the Ravelin alone with its Moat in the same Manner as has been set down,

1. Prolong the Faces of the Ravelin above its Moat, and from the Interfection of that Line and of the Moat put upon the Prolongation thirty Fathom, as A B.

2. Put fifteen Fathoms upon the Counterscarp of the Moat of the Body of the Place, placing the Compass in the Angle of the two Moats, as C D.

3. Join

3. Join DB together by a right Line, which Side, and the other AB, must be fortified with a Rampart, Parapet, Banquets, Moats, Covert-way and Glacis, like the Ravelin itself, the Distances of which are also here to be observed.

4. Having fixed this Work on the other Side of the Ravelin, place a small Reduit at the Head between the two Counter-guards, which are thus to be raised: First where the Moats of the Counter-guards intersect one another, erect from the same Angle a Perpendicular of twenty Fathoms, as EF; then divide the Faces of the Counter-guards into two equal Parts, as BG and AG, and from the capital Point of your Reduit draw a right Line toward the middle of the Faces, marked by the Point G, terminating on the Side of the Moat of the Counter-guards in H, and the Line FH will be the Face, which is only to be fortified with a Rampart, Parapet, Moat, Covert-way and Glacis, if need require. See the Plate C, Fig. VI.

Sect. 4. *To make a Ravelin, to be placed at the Entrances into Places.*

1. Having the Place for a Ravelin, you must erect a Perpendicular of twelve Fathoms from the Angle of the Counterscarp, as AB.

2. You must put at the same Angle six Fathoms upon the Counterscarp for Demi-Gorges, as AC, and AD.

3. Erect upon the Points CD Perpendiculars of four Fathoms for the Flanks.

4. Join the Flanks and the Capital together to have the Faces.

I

5. Draw

5. Draw a Moat round about this Work of two Fathoms and a half, parallel only to the Faces, and round before the Point. In this little Work is placed a great *Corps du Gard*, the better to guard the Gate and the Bridge, and present the Arms to the Officers.

6. That which is left of the Place designed for the Ravelin ought to be joined together, as if the *Corps du Gard* were not there, and fortified with Ramparts, Parapets, &c. as another Ravelin. See the Plate D, Fig. VII.

C H A P. VI.

To make a Horn-work before the Courtain.

1. **E**RECT a Perpendicular from eighty-five to eighty-eight Fathoms at the Point of the Ravelin or Half-Moon, as QG.

2. Draw from the Point G to each Side an Arch of sixty Fathoms.

3. Take from 114 to 118 Fathoms, which is most usual, and resect these Arches in EF, at the Angle of the two Counterscarps DR.

4. Join ED together by a streight Line, as also FR and FE.

5. Divide the Lines EF into two equal Parts, from the Middle of which set down a Perpendicular of twenty Fathoms GH.

6. Draw the Faces as for the Body of the Place; their Length is thirty-eight Fathoms.

7. For the Complement of the Line of Defence take twenty-one Fathoms two Feet, which join together after the End of the Face and of the Complement, to have the Flanks: Draw the Courtain also.

8. To

8. To make the Orillon and the hollow Tower go the same Way as is set down in Lib. III. Chap. II. only that you do not divide the Flank but into two equal Parts; Monsieur de Clermont would have allowed to the Orillon of the Square two fifth Parts of the Flank.

9. The Base of the Rampart is to contain eight Fathom; that of the Parapet three; that of the Moat twelve; that of the Covert-way five; the first and second Banquet are to have the same Wideness as has been mentioned above.

The TABLE.

	<i>Fathoms</i>	<i>Feet</i>
The Capital QG	88	00
The Wing DE	118	00
The Perpendicular GH	20	00
The Face EL	38	00
The Flank LN	15	03
The Complement, &c. HN, HM	21	03
The Courtain MN	38	05
The Line of Defence EM	84	04
The Base of the Rampart	08	00
The Base of the Parapet	03	00
The first Banquet	00	01½
The second Banquet	00	02
The Wideness of the Moat	12	00

To make a Ravelin before these Horns.

1. From the Angle of the Moat of the Horns erect a streight Line of twenty-four Fathom for the Capital O P.

2. From the Point B draw right Lines toward the Orillon of the two Bastions of the Horns terminating at the Moat, as OQ, OQ.

3. Draw

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3. Draw the Base of the Rampart, and the other Distances, as in the working of the Horn-work, only that the Moat ought not to be wider than eight Fathoms, nevertheless it must have its Rounding.

4. The Covert-way, the Places of Arms, and Glacis, are made as in the Body of the Place. See the Plate C, Chap. 4. Line 3.

C H A P. VII.

To make a Horn-work before the Bastion.

1. **F**ROM the Point of the Bastion draw a streight Line of eighty-six Fathoms, A B.

2. From the Point B draw to each Side an Arch of sixty Fathoms.

3. Take from 118 to 120 Fathoms, and resect those two Arches in C D, the Angles where the Moat of the Ravelin throws itself into the Moat of the Body of the Place, as E F.

4. Join E C, C D and D F, together by streight Lines.

5. Divide the Line C D into two equal Parts, from the Middle of which draw down a Perpendicular from eighteen to twenty Fathoms, as B H.

6. Draw the Faces as usually; their Length is to be thirty-eight Fathoms, as K I; the Complement is twenty-one Fathoms two Feet, as L N; lastly, all the rest is done as in the Horn-work before the Courtain, the Parts of which have the same Distance. See the Plate E, Fig. VIII.

C H A P.

C H A P. VIII.

To make a Horn-work with Shoulders.

1. **P**Rolong the Flanks towards the Field to the Length of the Courtain AB, CD.
2. From B and D draw a Perpendicular from twenty-five to twenty-eight Fathoms, as BE, DF.
3. From the Points EF raise other Perpendiculars from 118 to 120 Fathoms, as EG, HF.
4. Join GH together by a streight Line, which you shall divide into two equal Parts, and from the Middle of which you must bring down a Perpendicular of twenty Fathoms, as IK.
5. Draw the Faces as usually, the Length of which must be thirty-five Fathoms.
6. The Complement of the Line of Defence is found, by putting the Compass upon the Extremity of the two Faces, and then keeping one Point of the Compass standing in its Place, let the other fall upon the Line of Defence. Which is also to be done on the other Side, as LM, NO.
7. LM and NO are drawn together for the Flanks, as also MO for the Courtain.
8. To have the Orillon, take two fifth Parts of the Flank of this Work; the rest is made as usually in like Manner as the hollow Tower, or Flank retired.
9. The Base of the Rampart, &c. ought to have the same Wideness as the rest of the Horn-works, and to be drawn parallel as far as the Moat of the Body of the Place.
10. The Ravelin before this Work is made as already has been set down in Chap. VI. Lib. III. See the Plate F, Fig. IX.

C H A P.

C H A P. IX.

To make a Horn-work with a Crown.

1. **D**ivide the exterior Polygon of the Horn-work into four equal Parts, A B C D.
2. Take three Parts of these four, and describe them with an Arch at the Angle of the Moat of the said Work E.
3. From the Point E erect a Perpendicular as far as the Arch F.
4. Put the same three Parts of the Point F upon that Arch, as F G and F H, and join F G and F H together by a right Line.
5. From the Line F G and F H, let fall a Perpendicular of sixteen Fathoms, as I K, L M; then draw the Faces as usually, of which let the Length be twenty-nine Fathoms.
6. For the Complement of the Line of Defence take fifteen Fathoms, and then draw the Flanks and the Courtain as above.
7. Prolong the Faces of the Horns to twenty-seven Fathoms, as A N, D O, and join G N and H O together by a right Line.
8. Put twenty-four Fathoms upon the Wing of Horn, on the Side of the Place at the Points A D, as A P and D Q.
9. From the Points N and O draw right Lines towards the Points P Q, which terminate on the Side of the Moat of the Horn-work in R S.
10. To make the Orillon, divide the Flank into two equal Parts, of which the one serves for the said Orillon, and the other for the retired Flank. You are to observe, that the Flanks which join their Faces to the Moat of the Horn-work, are

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left without an Orillon and a retired Flank, as
NR, OS.

11. The Base of the Rampart, &c. and all the
other Distances, are formed as in the Horn-work.
See the Plate F, Fig. X.

C H A P. X.

To make a Crown-work before the Courtain.

1. **F**ROM the capital Point of your Ravelin
erect a Perpendicular of 100 Fathoms, and
if there be no Ravelin, take the Courtain of the
Body of the Place with the Brisure to draw two
Arches which intersect one the other before the
Courtain. From which Point of Intersection you
must do as I have already said concerning the
capital Point of the Ravelin, as A B.

2. Take the same 100 Fathoms, and make an
Arch from the Point B to each Side.

3. Take 113 Fathoms, and resect those two Arches
at the beginning of the Orillon CD and EF.

4. Join EB and BF together by right Lines,
and draw right Lines from the Points EF towards
the Orillon of the Place, terminating upon the
Side of the Moat GH.

5. Divide the Line EB, and the other BF, into
two equal Parts, from the Middle of which let fall
Perpendiculars, each from fifteen to sixteen Fa-
thoms, as IM, LN.

6. You are to draw the Faces as usually, the
Length of which must be thirty-one Fathoms, as
OP, QR; the Complement, &c. of sixteen Fa-
thoms, as ST, VW: The Flanks and Courtain
are made, as already has been frequently shewed.

7. Divid

7. Divide the Flank into two equal Parts, of which reserve one for the Orillon, and the other for the retired Flank.

8. The Base of the Rampart takes up eight Fathoms, that of the Parapet three; the first Banquet a Foot and a half, the second two Feet; the Wideness of the Moats twelve Fathoms; in the Covert-way and Glacis observe the same Breadth as there is round about the Body of the Place. See the Plate G, Fig. XI.

The Table for this Work.

	<i>Fathoms</i>	<i>Feet</i>
The capital Line A B	100	00
The exterior Sides B E, B F	100	00
The Wings E C and F D, with their Complements to the Orillons }	113	00
The Perpendicular	17	00
The Face	31	00
The Flank	13	03
The Curtain	30	00
The Complement of the Line of Defence }	16	00

C H A P. XI.

To make a Crown-work before the Bastion.

1. **E**RECT upon the capital Line of the Bastion a Perpendicular of 100 Fathoms, as A B.
2. From the Point B draw to each Side an Arch of 100 Fathoms.
3. Take ninety-two Fathoms, and resect those Arches at the Concourse of the two Moats, viz.
I 2 That

That of the Ravelin, and that of the Body of the Place, in CD, as ED, FC.

4. Join CB, BD, FC, and ED, together by straight Lines.

5. Divide the Lines CB and BD into two equal Parts, from the Middle of which let fall a Perpendicular of seventeen Fathoms.

6. You must draw the Faces, as usually, allowing to the Length of them thirty-one Fathoms; to the Complement, &c. sixteen Fathoms; to the Flank, thirteen Fathoms three Feet; to the Courtain, twenty-nine Fathoms three Feet; to the Base of the Rampart eight Fathoms; to the Base of the Parapet three Fathoms; and to the Banquets, Covert-way, and Glacis, as usually. See the Plate H, Fig. XII.

C H A P. XII.

To make a Ravelin before the Point of a Bastion.

1. **P**Rolong the Parapet of the Body of the Place above the Moat, so that it may cut it in QS.

2. From the Point of the Bastion erect a right lined Perpendicular, upon which put thirty-six Fathoms, beginning at the Moat, as CV for the Capital.

3. Upon the Prolongation of the Parapet by the Points SQ, put fourteen Fathoms for the Length of the Flanks, as ST, QR.

4. Join TV, VR, together, and you will have also the Faces.

5. Round about the Faces of the Flanks you shall draw the Base of the Rampart of eight Fathoms; that

that of the Parapet thirteen Fathoms, and the two Banquets as usually; and the Moat of twelve Fathoms, parallel to the Faces and the Flanks, with its Rounding, before the capital Point V, and the Flanks T R. See the Plate I, Fig. XIII.

C H A P. XIII.

To make a single Tenail.

1. **P**rolong the Flanks of the Body of the Place to 110 Fathoms, as A B C D.
2. Join B D together by a right Line; divide it into two equal Parts, and let fall from the Middle a Perpendicular of twenty-six Fathoms, as E F. But you must observe, that this Line ought not to be longer than twenty or twenty-two Feet, when there is a Ravelin or a Half-Moon before the Courtain of the Body of the Place.
3. Draw the Extremities of the Wings in the Point F, as B F, and D F.
4. Draw the Base of the Rampart eight Fathoms, that of the Parapet three, the two Banquets as usually, the Moat twelve Fathoms, the Covert-way and Glacis as for the Body of the Place.

The Ravelin before the Work.

1. Divide the Faces of the Tenail B F and F D, into two equal Parts, and set the Half of the one upon the Perpendicular erected upon the Angle of the Counterscarp, as G P.
2. From the Point G, toward the Middle of the said Faces of the Tenail, draw right Lines for the Faces of the Ravelin, as G L, and G M.

3. The Distances for the Body of the Place of the Ravelin are the same with those of the Tenail, only that the Moat belonging to it is no wider than eight Fathoms. See the Plate K, Fig. XV.

C H A P. XIV.

To make a double Tenail.

1. **P**rolong the Flanks of the Body of the Place to 110 Fathoms, as A B and C D, and join B D together by a right Line.
2. Divide the Line B D into two equal Parts, and let fall from the Middle of it a Perpendicular of twenty-six Fathoms, as E F.
3. From the Points B D draw right Lines to the Point F for the Faces, each of which must be divided into two equal Parts, as B G, D H.
4. Erect a Perpendicular upon the Angle of the Faces of forty-five Fathoms, as F J.
5. From the Point J, draw the Counter-Faces in the Points G H.
6. To the Wings, to the Faces, and Counter-Faces, draw the Base of the Rampart parallel of eight Fathoms, and all the other Distances as in the single Tenail. See the Plate K, Fig. XVI.

C H A P. XV.

To make a Bastion with Counter-Guards.

Formerly they were wont to put these Works before the Bastion, the better to cover them. The Structure is thus.

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1. Draw Lines parallel to the Faces of the Bastion of fifteen Fathoms, terminating upon the Counterscarp of the Ravelin or Half-Moon, and forming a Point before the Point of the Bastion, as A B C.

2. Draw the Base of the Rampart to these two Faces of eighteen Fathoms, as E D. All the other Distances are the same with those of the Ravelin or Half-Moon. See the Plate I, Fig. 14. C. XII. L. III.

C H A P. XVI.

Of the Structure of a Pentagon.

	<i>Fathoms</i>	<i>Feet</i>
1. THE Semi-Diameter	153	01
2. The exterior Side AB, CDJ,	180	02
3. The Perpendicular E F	25	00
4. The Face A F	50	00
5. For the Complement of the Line } of Defence F G, take	38	03
6. The Line of Defence G B	131	03
7. The Flank J G	22	02
8. The Curtain G H	73	04

The Explanation of this Table.

See Chap. 2. Book 3. There you will find all that is necessary for the Structure of a Pentagon; provided you take the Distances prescribed here, for those that are mentioned in the same Place. See the Plate F, Fig. 16.

Of the Structure of a Tenail in the Moat.

To justify what has been said above of the Line of Defence, observe this Work, the Structure of which is thus :

1. Set the Rule upon the advanced Flank of the Body of the Place, and draw parallel to that Flank from five to six Fathoms, which touches the Line of Defence before the Orillon in E B.

2. Divide the rest of the Line of Defence from B E, to the nearest Angle C, into two equal Parts, as B F, E G.

3. Take the Distance F G, between the Points of the Compass, leaving one upon the Point F: Carry the other from the Point G upon the Complement of the Line of Defence, marked F. Then fix one Point of the Compass upon the Point G, and carry the other from F, upon the other opposite Complement, marked H. Then join H F and J G together, to form the Flanks: Do the same for the Curtain H J.

4. Draw the Base of the Rampart of eight Fathoms to the Faces, and to the Flanks of the Tenail; and to the Curtain from four to five Fathoms. Then the Base of the Parapet of two Fathoms three Feet round about. You shall make the two Banquets as usually. See the Plate M, Fig. 16.



C H A P.

C H A P. XVII.

Of the Structure of a Hexagon, and other Polygons.

	<i>Fathoms</i>
1. THE Semi-Diameter takes up	180
2. The exterior Polygon	180
3. The Perpendicular	27
4. The Face	50
5. For the Complement of the Line of Defence	38
6. The Line of Defence	136
7. The Flank	25
8. The Courtain	71

The other Distances are equal to those of the Pentagon.

<i>Sect. 2. The Heptagon.</i>	<i>Fathoms</i>	<i>Feet</i>
1. The Semi-Diameter takes up	207	03
2. The exterior Side	180	00
3. The Perpendicular	27	00
4. The Face	50	00
5. For the Complement, &c.	38	00
6. The Line of Defence	135	03
7. The Flank	24	00
8. The Courtain	72	03

<i>Sect. 3. The Octagon.</i>		
1. The Semi-Diameter takes up	238	01
2. The exterior Polygon	180	00
3. The Perpendicular	28	00
4. The Face	50	00
5. For the Complement, &c.	28	00
6. The Line of Defence	137	03
7. The Flank	25	04
8. The Courtain	71	04

Sect. 4.

Sect. 4. *The Enneagon.*

	<i>Fathoms</i>	<i>Feet</i>
1. The Semi-Diameter	263	01
2. The exterior Polygon	180	00
3. The Perpendicular	32	00
4. The Face	50	00
5. For the Complement, &c.	38	00
6. The Line of Defence	138	00
7. The Flank	29	00
8. The Curtain	70	03

Sect. 5. *The Decagon.*

1. The Semi-Diameter	291	03
2. The exterior Polygon	180	00
3. The Perpendicular	36	00
4. The Face	52	00
5. For the Complement, &c.	38	00
6. The Line of Defence	135	00
7. The Flank	32	00
8. The Curtain	70	00

Sect. 6. *The Hendecagon.*

1. The Semi-Diameter	319	00
2. The exterior Polygon	180	00
3. The Perpendicular	37	00
4. The Face	152	00
5. For the Complement, &c.	38	00
6. The Line of Defence	135	00
7. The Flank	32	00
8. The Curtain	70	00

Sect. 7. *The Dodecagon.*

	<i>Fathoms</i>	<i>Feet</i>
1. The Semi-Diameter	347	04
2. The exterior Polygon	180	00
3. The Perpendicular	42	00
4. The Face	52	00
5. For the Complement, &c.	38	00
6. The Line of Defence	137	00
7. The Flank	37	00
8. The Courtain	69	00

C H A P. XVIII.

To make the Profil.

HAVING now treated of the Breadths and Lengths of the Parts of a Place, it is requisite to say something of the Height of the said Parts; or rather after what Manner to make the Profil of a Place. To which Purpose two Things are to be observed:

1. That you erect the Profil of the exterior Works after the same Manner as that of the Body of the principal Place; provided that you apply thereto the Heights, of which I shall speak as much as is necessary to be known, whereof the Breadths have been above exhibited.

2. That ten Fathoms of the Scale, of which I make use in delineating the Body of the Place, make but one, when I would make the Profil of the same Place. So that 100 Fathoms which I have applied to the Body of the Place, for this Purpose, afford only a Length of ten Fathoms.

The

The Profil of the Body of the Place.

For Example's sake, let us make the Profil of a Pentagon; and then observe that which follows.

1. Draw a long right Line, and there mark eleven Fathoms for the Base of the Rampart, beginning at the left Hand, as A B.

2. Put off one Fathom four Feet immediately behind the Point A, upon the same Line as A C. This Triangle marks out the interior *Talus*. And to mark out the exterior *Talus*, put one Fathom immediately before B, as B D. But in the Field you must allow a larger *Talus* to the Rampart, according to the Nature of the Ground.

3. Erect upon C D two Perpendiculars; each of which contain three Fathoms in Height, as C E, D F, and then join A E, E F, and F B, by a right Line, and that will afford the Height of the Rampart with its *Talus*.

4. Put four Fathoms of the Point E toward the right Hand, to mark out the Platform of the Rampart, as E G.

5. Erect upon G a small Perpendicular of a Foot and a half, for the Height of the first Banquet, as G J. Then draw from the Point J a Parallel to the Height of the Rampart a Foot and a half broad, as J H; that is, the Breadth of the Banquet. Then set another Perpendicular upon the Point H, of the same Height as H I; and from the Point J draw also another Parallel of two Feet broad, as L M, and then you will have both the Banquets.

6. Put four Feet immediately behind the Point G, as G N, and then upon that Point erect a Perpendicular of eight Feet, and N O; which done, join

the Point M and the Point O together, to get the interior Height of the Parapet with its *Talus*.

7. Prolong the exterior *Talus* BF two Feet farther, as HP, and join OP together to have the Breadth of the Parapet with its exterior *Talus*.

8. Put four Feet upon the first Line behind the Point B, as BQ; from which Point let fall the Perpendicular QR, of three Fathoms, and join BR together for the Scarp. Which done, put twenty Fathoms behind the Point B, for the Breadth of the Moat, as BS; then put two Points before the Point S, as ST; from whence let fall another Perpendicular of three Fathoms, as TV; then join VS together to have the Counterscarp of the same RV, and so the Moat will be entirely represented.

10. After this take thirty-six Fathoms, so far as the Ground will permit, and put them behind the Point W, upon the same first Line, as WA, and then join them together by a streight Line, to represent the Glacis. After this Manner you shall have the Body of the Place according to its Lengths, Breadths, and Heights. See the Plate N, Fig. 17.

The Profil of exterior Works.

The Profil is made as the preceding in respect of the seven first Points, saving only that the Base of the Rampart be no broader than eight Fathoms, nor the Rampart higher than fourteen Feet. As to the eighth Point of the Description of the preceding Profil, the only Difference consists in this, that the Moat is not larger here than twelve Fathoms, nor deeper than two and a half. All the rest is done as in the preceding. See the Plate N, Fig. 18.

C H A P.

C H A P. XIX.

*How to trace out the Draught of a Fortrefs
in the Field.*

AFTER you have seen the Manner of fortifying upon Paper, it is requisite for an Engineer, or any one that would discourse of Fortresses, to understand of what Breadth, Height, and Depth, their Parts ought to be; whence the one or the other Part derives its Defence, whether it be necessary to fortify one Part more than another; where to attack a Place, and after what Manner to frustrate the Enemy's Design. We shall therefore now shew how to trace out a Fortrefs in the Field: To which Purpose it is necessary to know which are the Angles of the exterior Polygons; being these that follow.

The Angle of the exterior Polygon.

	Degrees
The Angle of a Square is of	90
That of a Pentagon of	108
Of a Hexagon of	120
Of an Heptagon of	128
Of an Octagon of	135
Of an Enneagon of	140
Of a Decagon of	144
Of an Hendecagon of	147
Of a Dodecagon of	150

The

The Explication of this Table.

For Example: If you would draw a Polygon of five Bastions, which is called a Pentagon, of which every exterior Polygon must have the Length of the Line given A B, which is 180 Fathoms, then proceed thus:

1. Fix the Staff, upon which you have your Astrolabe, in the Hole that is made by the little Peg B, so that you may see through both the Sights of the Astrolabe, from the Point B, or the Place where your Instrument is fixed, the Peg A.

2. Count from the left Hand towards the right an Angle of 108 Degrees, which is the Angle of the exterior Polygons, to the Pentagon, (if you make an Hexagon, you take this Angle of 120 Degrees, &c.) there fix a little Peg, which you may see through the movable Sights, for Example, C: That done, fix a Cord or a Chain to the Peg B, and draw a streight Line toward the Point C, upon which you shall then put the Length of the first Line given A B, as B D.

3. Put the Instrument upon the Point D, so that through its Diopters or Sights you may see the Peg B. Then seek by the Diopters an Angle of 108 Degrees, and there fix another Peg, which you may see through the Diopters, as D E. That done, draw a streight Line from the Point D to the Point E, and then put the Length of the Line B D upon the Line D E, as D F.

4. Do this as many Times as is requisite for a Pentagon.

5. Divide

5. Divide the Flank into three equal Parts, and the first also into two others, in the Middle of which fix the Peg H. Then fasten the Chain to the Point H, and draw the Rounding, as upon Paper, with the Compass; That done, draw the Brisures of five Fathoms, and make in their Extremities two Arches to cut each other in I. Then fix in the Place of the Point I a little Peg, and with the Chain that is fastened to it, you shall draw the retired Flank.

6. To make the Rounding of the Moat, set the Peg upon the Point of the Bastion or Ravelin, and with the Chain draw the Rounding. See the Plate O, Fig. XIX, XX.

CHAP. XX.

To make the Streets in a Fortress.

1. **D**R A W to the Curtains of the Place a Parallel of ten Fathoms for the Place of Arms near the Rampart.

2. Draw all the Points made of that Line before the Bastion of the Place; for Example A B C D E.

3. Take the Demi-Gorge of the Place, or which is better, thirty Fathoms, and put them from the Center upon those Lines A B C D E, as a b c d e: Which Distances join together likewise by right Lines.

4. Take three Fathoms, and set them off from the Points A a, towards B b and C c, as F f, G g, which must also be done afterwards from B b, C c, D d, E e, &c.

5. Join

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5. Join Ff and Gg together by right Lines.
6. Take eight Fathoms of the Line Ff, and divide the rest into three equal Parts. Then take one Part of the three, and place it at the Points F and G, upon the Lines drawn in the grand Place of Arms, as FG, GL. Which done, put four Fathoms upon the same Lines, after the Points HL, as HM, LN. Lastly, join HL and MN together by right Lines.
7. Take the second Part of the three first, and put them after MN upon the same Lines, as MO, NP, and join the Line OP together. Which done, you shall replace four Fathoms after the Points OP, as QR, and then likewise join QR together.
8. Divide each Side, FG, fg, into two equal Parts, as ST, and join the Lines ST together by a right Line. Then put three Fathoms on each Side of the Points ST, as Sss, Ttt, and draw ST together; and these will form the Streets of your Fortress. See the Plate P, Fig. XXI.

BOOK

B O O K IV.

C H A P. I.

Of the principal Angles of a Fortress.

THIS Book contains the Explication of the Parts of a Fortrefs, whereof we have already spoken : By which are to be understood the Cavaliers, the Streets, the Places of Arms, the Counter-Guards, the Magazines, Gates, Back-Doors, Draw-Bridges, Bridges, and other Things. But we shall first begin to treat of the Angles.

Sect. 1. *To find the Angle of the Center of every regular Fortrefs.*

Divide the Circumference of the Diameter, which contains 360 Degrees, by the Number of the Bastions of your Fortrefs, and the Product of that Division will make the Overture, or Angle of the Center. For

1
360 (72
55

Example: Let us seek the Angle of the Center of a Pentagon ; to which Purpose, you must divide 360 Degrees by 5. For in regard our Fortrefs has no more than five Bastions, a larger Divisor cannot be taken : So that the Product of the Division being

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ing 72, we must say, that the Angle of the Center of a Pentagon has 72 Degrees of Overture.

Sect. 2. *To find the Angle of the Gorge, as it is called after Vauban's Manner; or the Angle of exterior Polygons.*

To find that Angle there needs no more than to subtract the Angle of the Center of the same Fortress of 180 Degrees, and that which remains makes the Angle of the Gorge. For Example: If you would know the Angle of the Gorge of a Pentagon, you must from 180 Degrees subtract 72; for that is the Angle of the Center of a Pentagon: Then observe what remains, which will be 108 Degrees, and say, That the Angle has 108 Degrees of Overture.

Sect. 3. As for the Angle of the Bastion, and all the rest, it is impossible to know what their Overtures are, in regard they are not always the same: So that it depends upon the Knowledge of the Engineer to make the Flanks, so that they may form a good Angle of the Bastion, according to which almost all the rest take their Measures. Consult our Authors upon this Matter. Nevertheless we shall here set down the Overtures of the principal Angles after our Manner of Fortification.

In a Square.

	Deg.	Min.
1. The Angle of the Center is	90	00
2. The Angle of the Gorge	90	00
3. The Angle of the Bastion	63	00
K 2	4. The	

	Degr.	Min.
4. The Angle of the Courtain	98	30
5. The Angle forming the Flank	81	30
6. The Angle forming the Front	112	30
7. The flanking Angle	67	30

In a Pentagon.

1. The Angle of the Center is	72	00
2. The Angle of the Gorge	108	00
3. The Angle of the Bastion	77	00
4. The Angle of the Courtain	101	50
5. The Angle forming the Flank	78	10
6. The Angle forming the Front	116	00
7. The flanking Angle	64	00

In a Hexagon.

1. The Angle of the Center is	60	00
2. The Angle of the Gorge	120	00
3. The Angle of the Bastion	87	00
4. The Angle of the Courtain	106	00
5. The Angle to form the Flank	74	00
6. The Angle to form the Front	121	40
7. The flanking Angle	58	20

In a Heptagon.

1. The Angle of the Center is	52	00
2. The Angle of the Gorge	128	00
3. The Angle of the Bastion	95	00
4. The Angle of the Courtain	102	30
5. The Angle to form the Flank	77	30
6. The Angle to form the Front	120	00
7. The flanking Angle	60	00

In

In an Octagon.

	Degr.	Min.
1. The Angle of the Center is	45	00
2. The Angle of the Gorge	135	00
3. The Angle of the Bastion	100	00
4. The Angle of the Curtain	103	00
5. The Angle to form the Flank	77	00
6. The Angle to form the Front	121	00
7. The flanking Angle	59	00

In the Enneagon.

1. The Angle of the Center is	40	00
2. The Angle of the Gorge	140	00
3. The Angle of the Bastion	100	00
4. The Angle of the Curtain	106	00
5. The Angle to form the Flank	74	00
6. The Angle to form the Front	125	00
7. The flanking Angle	55	00

In a Decagon.

1. The Angle of the Center is	36	00
2. The Angle of the Gorge	144	00
3. The Angle of the Bastion	100	00
4. The Angle of the Curtain	93	00
5. The Angle to form the Flank	87	00
6. The Angle to form the Front	115	00
7. The flanking Angle	65	00

In an Hendecagon.

1. The Angle of the Center is	33	00
2. The Angle of the Gorge	147	00
3. The Angle of the Bastion	100	30
4. The Angle of the Curtain	101	30
5. The Angle to form the Flank	78	30
6. The Angle to form the Front	125	00
7. The flanking Angle	55	00

In a Dodecagon.

	Degr.	Min.
1. The Angle of the Center is	30	00
2. The Angle of the Gorge	150	00
3. The Angle of the Bastion	100	00
4. The Angle of the Courtain	101	30
5. The Angle to form the Flank	78	30
6. The Angle to form the Front	128	00
7. The flanking Angle	52	00

Sect. 4. Of the Angle of the Bastions.

This Angle has occasioned great Disputes amongst the most Part of the Ancients, who have treated of Fortification: For some were of Opinion, that this Angle was to be always acute; others, that it only ought to be so in the Hexagon, and that it ought to be right in Figures of more than six Bastions; and this was the usual Practice of Monsr. *Antonine de Ville*. Others there are who maintain the contrary, and say, That the acute Angle is never to be allowed of, but in Figures that are under six Bastions, and that it always ought to be obtuse in a Fortress which exceeds that Number. True it is, that the greatest Number have been for the right Angle; and it were a sort of Ignorance to maintain the contrary. *Morsbeuser* made choice of this Angle in a Square of 60 Degrees, in a Pentagon of 72 Deg. in a Hexagon of 80 Deg. in a Heptagon of 85 Deg. 43 M. in an Octagon to an Hendecagon of 90 Deg. *Freitag* made choice of this Angle from a Tetragon of 65 Deg. to a Pentagon of 74 Deg. from a Hexagon of 80 Deg. to a Heptagon of 84 Deg. 17. Min.

from

from an Octagon of 87 Deg. 30 Min. and from an Enneagon to a Dodecagon of 90. But he soon altered his Opinion, maintaining that this Angle ought to be from a Tetragon of 60 Deg. to a Pentagon of 69; from an Hexagon of 75, to a Heptagon of 79 Deg. 17 Min. from an Octagon of 82 Deg. 30 Min. to an Enneagon of 85 Deg. to a Decagon of 87 Deg. to an Hendecagon of 88 Deg. 38 Min. to a Dodecagon of 90 Deg. *Goldman* makes use of this Angle for a Square of 65 Deg. for a Pentagon of 69 Deg. for a Hexagon of 75 Deg. for a Heptagon of 79 Deg. 17 M. for an Octagon of 82 Deg. 30 Min. for an Enneagon of 85 Deg. for a Decagon of 87 Deg. for an Hendecagon of 88 Deg. 38 Min. for a Dodecagon of 90 Deg. *Pascha* takes it for a Square of sixty Fathoms, and augments it still by five, according as the Polygon gains more of the Side. But they who have been accounted most skilful in the Art of *Fortification*, were always, as I have said, for the right Angle, though it be alledged, That in making it acute, there is room for more Firing from the Courtains; or that in making it obtuse, it is more capable to withstand the Enemy's Batteries, and the Injuries of Time. The Reason that kept them so fixed to this Opinion, was, that in their Time they made their Breaches with the Cannon, so that this Angle being right, it had all the Perfection that could be desired; whereas the making it obtuse, diminished the Capaciousness of the Bastion, and of its Flank; besides, that the same Battery could play upon both Fronts: And by making it acute, the Point of it was so soon broken by the frequent Discharges; more especially, if several Guns played at a Time; besides, that bad Weather

more easily ruined that Point. But to speak the Truth, we ought to believe, that this Angle, whether right, acute, or obtuse, ought never to trouble our Thoughts, provided it be not less than sixty Degrees, nor much more than 100: For the Breaches are now made by Mining, wherein there is no more Trouble to carry the Point of a Bastion with an obtuse Angle, than with an Angle either right or acute. Moreover, there is this in it, that Breaches are rarely made in the Point of a Bastion, but in one of the Fronts, to the end, that in passing the Moat the Assailants may not be exposed to more than one Firing; so that provided the Angle be well able to resist the Injuries of Time, it is enough. However, much more than 100 Degrees are not to be exceeded, because that being more open, it would require the capital Line to be short; in which case, the Bastion would not have room sufficient.

Sect. 5. *Of the Angle of the Curtain.*

Engineers cannot agree concerning the Overture of the Flank; so that every one orders it according to his Fancy. *Erhard* makes the Flank perpendicular to the Faces of the Bastions; and his Reason is, because the Flanks, being oblique above the Curtain, that is to say, making an acute Angle with it, are much more exposed to the Enemy, and consequently more difficult to be ruined, as not being battered by the Cannon but very obliquely: But granting that this were so, it is no less a Truth to say, that as they are but little exposed, so neither do they not survey very far; and it is impossible to make good Embrasures

embrasures upon a Parapet, ordered after that Manner. For to play the Cannon above the Parapet, is to make it impossible to preserve it in a good Condition; besides, that a Flank disposed after that Manner, can never defend the Passage of the Moat, nor flank the Breach, nor in the last Place, uncover the Covert-ways. As for Monsieur *le Chevalier de Ville*, who makes the Flank perpendicular to the Courtain, he has more Reason for what he does, than *Erhard*; though his Flanks are less than those which Monsieur *Vauban* makes use of, and that they do not batter the Moat sufficiently, nor the Counterscarps, which is the most essential Part of the Defence. Besides, it is but too well found by Experience, that when the Counterscarp is gained, the rest holds out but a short Time, the Reason of which, if it be demanded, is because the disposing of the Places is so disadvantageous, that one Day sees them reduced to Dust; and the Embrasures made upon these Parapets, perpendicular to the Courtain, are too acute, especially if it be required that they should clear the Covert-ways. I know it may be said, that it is easy to make an Orillon, or Ear, and a retired Flank in a circular Fashion: But the Orillon will be too feeble, unless you allow it the half of the Flank, and the Remainder will not suffice for its Defence, not having room enough for several Pieces to be placed upon it; besides that, there must be a Mixture of great and small Shot, which will cause an inevitable Trouble.

Monsieur *Pagan*, a Person experienced to Perfection in the Art of War, and one who has justly acquired the Reputation of being one of the most skilful Engineers of our Time, was the first that altered

altered the disposing of Flanks perpendicular to the Courtain, by allowing them much more Overture; for he makes them perpendicularly upon the Line of Defence; and he gives very good Reasons for it, in his Book of Fortifications; where he says, That his being present at above twenty Sieges, convinced him, that Flanks perpendicular to the Courtains, were of little Durance: And he wonders that the Reputation given to the *Hollanders*, for their Perfection in the *Art of Fortification*, should be so great, since the Places fortified according to their Method, make so little Resistance; and for that there is not one which is well defended from the Cannon: Nevertheless, we may presume to say, that Monsieur *Pagan's* Method is not altogether without Defects; for the Enemy may batter a Flank so disposed, before he comes upon the Covert-way: Therefore, to make the best of all the Advantages which both the one and the other produces in his Defence, Monsieur *Vauban* allows an Overture to this Angle, from 98 Degrees to 106, as may be seen, Book IV. C. 1. Sect. 3. For by this Means the Embrasures made in the Parapet in this Flank, perfectly uncover the Moat, and the Covert-way. And though Monsieur *Vauban* should not have made this Flank in a crooked Line, by Means of the Orillon and the retired Flank, however it ought to be preferred before others; because the Ravelin covers the Overture which is allowed it above the Perpendiculars to the Courtain, and consequently it is not too much exposed; besides that it considerably enlarges and diminishes the Faces, which are the largest Parts of a Fortification.

C H A P. II.

Of the Flank.

HERE we must repeat what we have already said, That though the largest Flanks are the best, nevertheless it is a Thing disputed among the Engineers, *Morsbœuser* made the Flank to a Square of 16 Fathoms ; to a V, of 18 ; to a VI, of 20 ; to a VII, of 22 ; to an VIII, as far as a *Dodecagon* of 24. *Freittag* made it to a Square of 12 ; to a V, of 14 ; to a VI, of 16 ; to a VII, of 18 ; to an VIII, of 20 ; to a IX, of 22 ; to X, of 24 ; which Length he retains also in *Polygons* of 11 and 12 Bastions. *Goldman* made it a Square of 12 ; to a V, of 16 ; to a VI, of 18 ; to a VII, of 20 ; to an VIII, of 22 ; to a IX, till he came to *Polygons* of 12 Bastions of 24 Fathoms. In general, the *Hollanders* make their Flanks to a Square of 16 Fathoms, 2 Feet ; to a V, of 18 Fathoms, 2 Feet, to a VI, of 19 Fathoms, 2 Feet ; to a VII, 19 Fathoms, 5 Feet ; to an VIII, 22 Fathoms, 1 Foot ; to a IX, of 22 Fathoms, 1 Foot and a half ; to a X, 23 Fathoms, 2 Feet ; to a XI, of 24 Fathoms, 2 Feet. Monsieur the Count of *Pagan* allows the Flank in a Square, 19 Fathoms, 1 Foot ; to a V, 24, &c. as you may see, Lib. 3. Chap. 16. and 17.

C H A P. III.

Of the Faces.

AS the Face is the most dangerous Part of a Fortrefs, and for that it is extremely exposed to the View of the Enemy, it is requisite that it should be as short as may be; for that, by how much it is the more advanced towards the Field, by so much it is the more liable to be attacked. Whence it comes to pass that the Enemy of late generally makes choice of that Part to begin his Breaches. As to the Length of the Faces, the Engineers differ as much one among another, as they do about the Flanks. *Adrian Metins* would have the Face to carry two third Parts of the Courtain. *Monsieur, the Count of Pagan*, allows it in a Square fifty-five Fathoms, and permits the same Length for the Polygons. *Freitag* would have the Face to be always forty-eight Fathoms, according to the Practice of all the *Hollanders*. As for the Length of the Faces, after *Vauban's* Method, see Chap. 16. of the third Book.

C H A P. IV.

Of the Orillon, and Flank retired; together with the Brisure, or Place where the great Guns are to be planted.

AS for what concerns the erecting of the Orillon, and Flank retired, according to *Monsieur de Vauban's* Method, there needs no more
than

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than to read what he has written thereupon, in the second Chapter of his third Book. But here is a new Method ; which though it is not better, however it is as good.

1. After the Out-Lines of the Fortrefs are drawn, divide the Flank of one of the Bastions into three equal Parts, and the Face of the opposite Bastion into two, as A B, B C.

2. Draw from the Point B, which makes the middle of the Face, a Line through the third Part of the Flank, which is the nearest to the Angle of the Shoulder D, prolonged in the Body of the Bastion of five Fathoms, as D E.

3. Divide the same third Part of the Flank into two equal Parts ; as F G and G D, from which Point G, erect a Perpendicular of about two Fathoms, as G H. Lastly, Set the Compass upon the Point H, and so draw the Rounding of the Orillon, joining F D together.

4. Draw from the re-entring Angle of the Moat P, a right Line through the Angle of the Curtain L, prolonged in the Body of the Place, of an equal Bigness to the Line D E, that is to say, of five Fathoms, as K I ; to the end that you may have the Brisure, where you may place the Piece of Cannon that points towards the Half-Moon, and cannot be battered from the Field ; because it is, as it were, covered by the Ravelin. Lastly, To make the Rounding of the Flank retired, take the Distance K E, between the Points of the Compass, and make Sections toward the Moat, in L ; from whence afterwards draw the Arch from K to F.

It cannot be said, but that these Orillons are very good ; for these Roundings give less Advantage to the Enemy's Cannon, and enlarge the Room,

Room, as well for placing the Cannon, as for the Musketeers. If you object, That the Distance from that Part where the Enemy may pass the Moat, is too great ; I answer, That the principal Defence of the small Shot to hinder the Passage of the Moat, consists in the Tenail ; where you may set a Body of Musketeers to fire continually.

Upon this Method, *Monfieur de Clermont* observes, That the Orillon of the Square would be too little, if you allow it no more than the third Part of the Flank, as to the Polygons ; and therefore he requires two fifth Parts of the same Flank for the Orillon. See the Plate P, Fig. XXII. at the End of the third Book.

CHAP. V.

Of the Courtain.

IN regard the Courtain ought to cover the greatest Part of a Work, it is requisite that it should be of a reasonable Length ; that is to say, that it should never be shorter than sixty Fathoms, and never longer than an hundred. *Morsbeuser* allows it seventy-two Fathoms ; and *Freitag* as much. *Goldman* would have the Length to be of ninety-six Fathoms ; *Anthony de Ville* 100. *Tieu* makes it seventy-four Fathoms in Length ; *Hinsel* eighty-four. *Monfieur de Clermont* allows it three fifth Parts of a Polygon ; the Count *de Pagan* sixty Fathoms. *Monfieur de Vauban* forms it according to the Plurality of the Bastions : As you may see, Lib. 3. Chap. 17.

As to the Figure of the Courtains, there are some Engineers, who will have them to be as is marked

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at the Letter A; of which the Construction is such. See the Plate P, Fig. XXII. at the End of the third Book.

1. Divide the Line A B into five equal Parts, as AD, DM, NC, and CB, and take one for the Demi-Gorge, as B C, A D.

2. Divide the same Line A B into three equal Parts, and take one for the Capital, as B E, A F.

3. Where these three Parts are marked, as at R and G, bring down from the Points R G, two Perpendiculars, of which let each have the third Part of the capital Line for its Length, as R H and G I, and then join H and I together by a right Line.

4. Make upon the Points D and C, the Angle of the Courtain of 100 Degrees, and allow to the Flank the Length of the Demi-Gorge, as D P and C Q. This being done, join E Q and D P together, to have the Faces. The Defects of the Courtain are, 1. That it is too short. 2. That the Fortification takes up too much Room. 3. That it renders the Bastion too acute.

Others there are that form an Angle without-side, as that which is marked with the Letter B. The Construction of which is after this Manner:

1. Divide the Line A B into five equal Parts, as A C, C D, D E, E F, and F B.

2. Divide the first Line A B into three equal Parts, and allow one for the Capital, as A I, and B K; then join H I and B K together, to gain the Faces.

3. Divide the Courtain C F into two equal Parts, and upon the Middle, marked with the Letter L, erect a Perpendicular; which has the half of the Face G K; as L M.

4. Draw

4. Draw from CF two streight Lines to the Point M, and your Curtain will be made. See the Plate P, Fig. XXIV.

Others make the Curtain of a circular Figure withinside, like that which is marked C: The Construction of which is as follows. See the same Plate, Fig. XXV.

Having observed what has been said touching the three first Points of the preceding Curtain, take the Extremities of the Curtain BC, and make two Arches to cross or cut one another underneath; and from this Point of the Intersection draw an Arch from one End of the Curtain to the other.

Lastly, There are others that form the Curtain of a circular Figure withoutside, like that which is marked D. The Construction of which is like to that which we have already described, only that here you make the Intersection above the Curtain in E: From which Point you afterwards draw the Arch from one End of the Curtain to the other.

The Breast Curtains are those which are drawn streight out-right from one Flank to another. See the same Plate P, at the End of the third Book, Fig. XXVI.

CHAP. VI.

Of the Parapet.

IN regard that this Work is raised to cover the Cannon and the Soldiers which defend the Place, it must be allowed a reasonable Height and

and Breadth. *Cellarius* allows it six Feet in Height, with a Foot of sloping within Side; to the end the Soldiers may be able to stand the better when the Parapet is reared after that Manner. The Height withoutside from the Cordon ought not to be above four Feet, because the sloping which is made by those different Heights, inward and outward, gives the Soldier an easy View of the Covert-ways, and the Moats that are before him. As for the Thickness of the Parapet, *Monsieur Clermont* allows it for the Basis, the third Part of the Basis of the Rampart. The Count *de Pagan* makes it three Fathoms broad. Of which Opinion are several others, as *Goldman*, *Freitag*, and *Monsieur Vauban* himself. So that we may boldly say, That the Thickness of the Parapet is good, when it is not less than eighteen Feet, nor broader than twenty four. For being weaker, the Parapet cannot long resist the Force of the great Shot, which would soon level it with the Earth; and being thicker, it would hinder the Soldiers from the Sight of the Moat and the Covert-way.

If you would line the Parapet, it must be allowed a little sloping, that the Soldiers may have the better Footing. The best Lining of Parapets is with Turf. As for the Earth or Mould which you are to make use of in erecting a Parapet, it is very requisite to mix it with Withy Twigs, or Brambles, and to sow it with any Weeds that take a deep Root, to bind the Earth together, so that the Cannon may not easily crumble it down. Hay of *Burgundy* is also very good for this Purpose, in regard that there is no Plant that puts forth more or deeper Roots.

C H A P. VII.

Of the Banquets.

AT the Foot of the Parapet, upon the Platform, are usually made two little Steps or small Banks, of which the first is about two Feet broad. *Goldman* makes it four Feet, *Freitag* three, the Count of *Pagan* two, *Monsieur Clermont* the same; and one Foot, and one Foot and a half high; wherein they all agree. There are two made, for that the Soldiers are not all of an equal Height. So that the low Men are placed upon the upper Step or Bank next the Parapet, and the taller upon the lowermost: So that every one may have a View from the Parapet, and Discharge at his Ease.

C H A P. VIII.

Of the Rampart.

THIS Work is the principal Piece of a Fortification; and therefore the Rampart ought to be higher and broader than any of the rest of the Parts. *Fournier* allows from the Breadth of the Rampart from fifteen to twenty-five Paces; and for the Height, from the Level of the Field from fifteen to twenty-five Feet. *Freitag* takes for the Base of a Square nine Fathoms; of a Pentagon ten; of a Hexagon eleven; of a Heptagon twelve; of an Octagon thirteen; of an Anneagon fourteen; and observes this Breadth in all other Polygons. The Height of the Rampart he thinks sufficient if it

it be but three Fathoms ; and he raises the said Rampart above the Level of the Field three Fathoms. Monsieur *Clermont* would have the fourth Part of the Face allowed for the Base of the Rampart, or in the Field from eight to twelve Fathoms ; believing that a larger Breadth would not only be useless, but also prejudicial, by reason of the great Space of Ground it would take up, and the vast Quantity of Earth it would require. Monsieur *de Vauban* never makes the Basis larger than eleven Fathoms, alledging the same Reason that Monsieur *Clermont* brings. The Height of this Rampart never exceeds four Fathoms, whether to cover the Houses of the Place, or to command the Enemy's Approaches : For being lower, the Garrison within could never command the Enemy's Works. If they tell me that in some Places a higher Rampart is requisite ; I answer, That a good Cavalier supplies that Defect, without raising the whole Rampart any higher. The upper Breadth of the Rampart ought to be from four to six Fathoms ; for being too narrow, it would require that the Parapet should be made too broad to consume the rest of the Earth, appointed for the Rampart ; besides, that it would be prejudicial, because too broad a Parapet hinders the Soldiers from the Sight of the Moat ; and being too large, the Remainder of the Earth would not suffice to make a good Parapet, which is also very dangerous. As for the sloping of the Rampart, it has been said above, That there ought to be allowed to the *Talus*, or sloping of the Rampart, as the Earth tumbling down from the Top to the Bottom takes up of itself. For every Body knows, that, according to the Badness of the Earth, the sloping ought to be more or less, the

better to sustain the Rampart. The best Earth is that which is called gray Clay, next to that the slimy Earth, because that by reason of their Clamminess, they better resist the Inconveniencies of Heat and Rain; besides they bind exactly well together, support themselves with little sloping, and feed the Roots of Weeds and Grass better. To every Foot of Earth, where the Rampart is raised, two Branches of Willow are to be set no bigger than a Man's Thumb: Besides that, the Earth is to be so hard rammed down, that it may sink four or five Inches, and that there remain not above seven or eight. Lastly, You ought to sow with Hay-Seed and Weeds upon the outside in every Row, to the end the Earth may intermix with the Roots. Nor is there any Herb that casts forth more or deeper Roots than the *Spanish* Trefoyle, or winged Clover. Moreover, you ought to erect the Platform so, that the Plane of it may decline somewhat towards the City, to carry off the Water. When you plant Trees upon the Rampart, it is a great Ornament in Time of Peace, and a good Provision in Time of War. There are some Engineers that do not like this Advice; for they say that the Wind makes such a Noise, when the Branches hit one against another, that the Men can hardly hear one another: Besides that, it is a great Hindrance to the Centinel, which is a Consideration not altogether to be rejected. Lastly, We cannot pass by in Silence the Fancy of some Men, who proportion the Thickness of the Rampart to the Number of the Bastions of the Fortification; as if a Hexagon ought not to have as good a Rampart as a Decagon. I would fain ask them, Whether small Places are not attacked

attacked with the same Arms as great ones? If they answer, That there is more Earth taken out of the Moat of a large Place, than a small one; we reply, That it may be spent upon the Glacis: For that the larger the Glacis's are, the better they are.

C H A P. IX.

Of the Embrasures and Merlons.

MANY have proposed several sorts of Embrasures, but the best are those which are streight and narrow withinside, and wide towards the Field; to the end that the great Guns may play with more ease toward the Right and Left. The Merlons, to the end that they may be good, ought to be made of Earth, the most easy to be tempered that may be: And this Earth ought also to be mixed with Withy Twigs, or Brambles, provided they take Root, after which they are to be lined with good Turf.

C H A P. X.

Of the Moat in the Body of the Place.

I N regard that every Fortrefs ought to be environed with a Moat, we shall briefly examine which sort of Moats are first to be preferred. Some make them broad, others narrow; one draws the Moat parallel to the Faces, another draws them narrower toward the Point of the Bastion, than in

any other Places. Lastly, one is for a dry Ditch, another for a Moat that is full of Water. One prefers a Moat very deep, but not so broad; another would have it broad, but not so deep. Let us examine every one of these in order. The Count of *Pagan* makes his Moat for a Tetragon sixteen Fathoms broad; and for Polygons of twenty, his Depth does not exceed four Fathoms. Monsieur *Clermont* takes from sixteen to twenty Fathoms, for the Breadth of the Moat, without any regard to the Plurality of Bastions, and makes it hollow from eighteen to twenty Feet. *Fournier* would have it broad from fifteen to twenty-five Paces, and deep from fifteen to twenty-five Feet. *Cellarius* makes his Moat three Fathoms deep, and broad at the Top about nineteen, and at the Bottom near thirteen. Monsieur *de Vauban* prefers Monsieur *Clermont's* Way before all the rest, as to the Breadth and Depth of the Moat: For as to the Way of drawing out the Moat, Monsieur *Clermont* makes it narrower toward the Point of the Bastion than toward the other Parts; more especially if the Flanks are large; for he says, that otherwise, it would be requisite that the Moat should be as large as the Length of the Flank, or else much narrower; and in the first case there would be a Necessity of making it very shallow, which would render it defective, for that the Enemy would easily shoulder himself into it. And supposing it were of a reasonable Depth, there would be Ground which no Body would know what to do with, by reason of the extraordinary Wideness. And in the second case, there would be one Side of the Flank that would not uncover the Moat, which would be against the Rules of Fortification. Others answer first, that if
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the Moat were as large as the Flank, with a moderate Depth, that Wideness would hinder the Enemy from crossing the Moat, without great Loss of his Men. But if the Depth were a little more than ordinary; and it should be asked, what should be done with the Earth taken out of the Moat? they reply, it would make the Glacis. The Learned may judge as they please; but for my part, I hold with them that are for making the Moat parallel to the Line of Defence. If they still object, That the Rounding of the Moat being as large as in other Places, all the whole Courtain and Face of the opposite Bastion cannot be discovered; we must answer, that if they would uncover those Parts above the Rounding, they ought to make no Moat at all, because the Point of the Bastion itself is not proper for that. Add to this, that if the Moat be made narrower toward the Point of the Bastion, the Enemy having once gained the Point, the Earth of which filled one part of the Moat, he will easily pass it by, throwing Bavins over the Ruins of the Bastions, which will shew him, as I may so say, the way to enter directly into the Bastion.

The next Question is, whether a Moat full of Water is to be preferred before a dry Moat? which a Distinction between the great and small Places will quickly decide. As for great Fortresses, it cannot be denied but that dry Moats are to be preferred before those full of Water. Some will object, That a Moat full of Water secures a Place against Scaladoes and Surprizes; besides that, is very hard to be filled up; and that it affords great Trouble to the Enemy, that would either pass it, or cover himself, or fight within it: And that

on the other Side, besides that a dry Ditch is extremely exposed to Surprizes, very easy to be filled up, and no less easy to be passed; it is very proper to cover the Enemy in making of Mines, by Means of which he may blow up a great part of the Place. But I answer to this, that as well a Moat full of Water hinders the Sallies of those within, without the Help of Boats, which make so great a Noise, that it is impossible but the Out-Centinels near the Place besieged, must hear it; and the same that is to be said of the Sallies, is to be said of the Retreats. Beside, if the Water that fills the Moat be not a running Stream, it begets an unwholesom Air, causes frequent Distempers, and renders the Soldiers less courageous, by reason of the noisome Stenches that arise out of it; and on the other Side, besides that, a dry Moat is more commodious for Sallies, and safe Retreats; there is no Fear of Sicknes proceeding from noisome Water, and unwholesom Air. To say something of the Convenience of Mines, which the Enemy has to make, you must make a Cuvette, or a little Dike in the middle of the Moat, from fifteen to twenty Feet broad, and very deep; for the deeper it is, the better it is: Surround it with a good Parapet with Palisadoes round about; and so you will be secure from Mines and Surprizes. As for little-Fortresses, a Moat full of Water is better than a dry, because Sallies, Retreats, and Succours, are not so necessary as in great Places. The Moat is also to be rounded before the Point of the Bastion, to the end that it may be of the same Wideness quite through, and that it may not advance too far into the Field; which it would do if it were pointed. You may also set a *Corps de Gard* upon this

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this Rounding, the better to defend the Covert-way. Lastly, When you would line the Moat, they never allow it any great Talus or Sloping; only they allow it such as the Earth of the Rampart, and the Moat gives it of itself.

CHAP. XI.

Of the Moat belonging to the Outer-Works, and the Avant-Moat.

THE Moats belonging to Outer-Works ought to be neither so great, nor so deep, as that which belongs to the Body of the Place: For a Wideness of twelve Fathoms suffices for these Moats, being hollow from twelve to fifteen Feet.

In short, there are some Engineers, who make a little Moat about the Glacis, though others practise quite contrary. The first pretend that the Earth taken out of the Moat, serves to fortify the Glacis, and secure the Covert-way. On the other Side it is said, that the Avant-Moat serves only to hinder the Sallies and Retreats of the Garrison: And this Reason prevails; for if you have need of Earth, the better to secure your Covert-way, you may make the Moat of the Body of the Place deep, and employ the Earth which you take from thence, for that Purpose. If you think that this Moat prevents Surprizes, and the Approaches of the Enemy; I answer, That a good wide Glacis will do the same, without being at so much Charge for an Avant-Moat. Nevertheless, sometimes they are constrained to environ the Glacis with such a Moat: They

They make it five Fathoms wide, and two deep. Such a Moat as this you may see about the Citadel of *Strasburgh*.

C H A P. XII.

Of the Covert-way, and of the Glacis.

A GOOD Covert-way will require at least five Fathoms in Breadth, especially if the Ground will permit it; for one broader is useless and prejudicial, unless its Parapet be higher than ordinary; otherwise it is easily pierced by the Enemy's Batteries: And one less wide, is defective in this, that there is not room for the great Guns and Men, but one will hinder the other. Besides, that when it is too narrow, it is not flank-ed on so many Parts as it ought; and it may be said, that this Part must be then too much in View of the Enemy, whose chiefest Effort in a Siege it is, to make himself Master of the Covert-way.

This Covert-way has no other Security than the Glacis, which serves it for a Parapet round about. The Wideness of it ought to be at least from thirty-six to forty Fathoms, losing itself insensibly in its Inclination towards the Field. But the better to secure the Covert-way, we must say that the largest Glacis's are the best; for that by this Means, the Enemy lies more open; and the less it has of Sloping, the better they are, because the small Shot is the more secure in the Covert-way, and does more Execution. In short, there is nothing to be suffered about the Glacis, that may
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favour the Enemy in his Approaches : So that if the Glacis be higher than five Feet above the Covert-way, you must put one or two Banquets below, as need shall require, for the short statured Soldiers.

C H A P. XIII.

Of false Brays.

HERE it is, that some will ask me why the *French* admit no false Brays in their Fortifications, as being a second Defence, and an admirable Work to dispute the Counterscarp with the Enemy, and to hinder him from crossing the Moat. Moreover it is certain, that small Shot does more Execution from a low than an high Place. Besides, that the small Shot placed in the false Bray, doubles the Defence of it, as that Work doubles the Defence of the Place. But if you talk of the Defence, Why do you then put the Counterscarp before the Faces, knowing that those Parts defend nothing? You will answer, That this is to dispute the Passage of the Moat. But consider, that the Enemy having broken the Parapet of the Point, may afterwards pierce with his great Guns the Walk that runs all along the Face: Besides that, the ruining of that Work is very advantageous to the Enemy, who would willingly have wherewithal to fill the Moat. As for the part of the false Bray that is before the Courtain, it is no longer good, because it does not flank the Faces of the Bastions, nor hinder the Passage of the Moat, which is objected always for

for the principal Reason. Nevertheless the Remainder of that Work, which is before the Flank, will be good: But know that this Part is easily rendered unserviceable, by the Ruin of the Rampart, and the Parapet of the Flank, which falling withinside, fills up its Platform: And if the Rampart be lined, the Splinters of it maim the Soldiers that guard the Flank of the false Bray. To remedy which Defects, the *French* now-a-days erect Tenails in the Moat before the Courtain, and before the Flanks separated from the Body of the Place, by a little Moat, to the end the fall of the Rampart of the Body of the Place may not kill or wound those that are in it, being lined with Walls. There is nothing of all that you talk of false Brays, that can be attributed to these Tenails; besides, that they cast not the half of what those other Works do.

C H A P. XIV.

Of Cavaliers.

Cavaliers are one of the best Defences of a Place, beause they most notably scour the Field, which obliges the Enemy to open his Trenches at a great Distance, in regard these are as so many second Bastions, which are opposed to the Enemy. And moreover, that they defend the Passage of the Moat, command the Covert-way, and above the Glacis; it is certain, that being well disposed, they may defend the Head of the Breach, which the Enemy shall make in the Face of the Baition, wherein those Cavaliers are erected,

erected. Now in regard that Opinions are different, as well in respect of the Place where they are to be set, as in regard of their Figure, let us see the Reasons both of the one and the other.

I. There are some that would have the Cavaliers placed upon that part of the Courtain, which discovers the Face of the opposite Bastion ; that is to say, upon the Lines of the second Flank, as A ; the Construction of which is such. See the Plate Q, Fig. XXVII.

1. Bring down a streight Line perpendicularly under the Flank, and upon this Line put two third Part of the Demi-Gorge, as A B.

2. Divide the Line A B into two equal Parts, as A C, C B, and prolong perpendicularly the Point C, till this Prolongation be equal to the Demi-Gorge, as C D.

3. Bring down also a Perpendicular from the Point D, of the Length C B, as D E ; and at length join B E together by a right Line.

4. Having raised the Cavalier to a just Height, they give it a Parapet of three Fathoms, and two Banquets, as is usual.

1. But it may be objected against this Situation, That the Cavalier does not flank, but very obliquely ; and by Consequence, that the Effects of it are of little Consequence.

2. That the Ruins which the Enemy's Cannon will make, as being opposed to it in Front, falling between the Courtain and the Cavalier, will hinder the Execution of the small Shot of the second Flank.

II. 1. Others

II. 1. Others lodge the Cavalier in the middle of the Courtain, and give it a triangular Figure; alledging, That in that Part, one and the same Cavalier may flank two Faces of the Bastions. To which it is answered, That a Cavalier cannot be erected after that Manner, but in Places which have more than half the Courtain for the second Flank; which would be very difficult, unless it were in Cities where the Angles of the Polygon are of a very large Overture. For to say, we ought to make these second Flanks very large, as well to augment the Firing from the Courtain, as to gain room for placing of the Cavalier; this is to make Bastions in a Place, that serve for nothing; because, that by this Means, the Flanks are made so small, that they seem to be only for Ornament.

2. That the Enemy stands in no fear of the Firing from a Cavalier disposed after that Manner, when once he is lodged upon the Counterscarps, because it is too high, and the Cannon cannot plunge low enough.

The Construction of this Cavalier is such: See the Plate Q, Fig. XXVII. B.

1. From the Courtain let fall a perpendicular Line, and set off there above fourteen Fathoms; as A B.

2. Take that Distance, and draw from the Point B a Circle.

3. Divide this Circle into three equal Parts, beginning from the Point A; as, A C, A D, and C D; which join together by right Lines; and this shall be the Base of the Cavalier.

4. Draw

4. Draw on the Sides A C, and A D, the Base of the Parapet of three Fathoms. But it is to be observed, That these Cavaliers are not to be erected but from nine to ten Feet above the Platform of the Rampart, unless there be very strong Reasons to raise it higher. In the mean Time, it is very true, that this Cavalier is not better than the preceding, because the Angles of it are very acute; for when the Angle A is carried away, all the rest is worth nothing; since neither Cannon nor Soldiers can subsist upon the Side A C and A D, by reason of the Enemy's continual playing upon them.

III. Some raise the Cavaliers upon the Platform of the Bastion, and dispose it in such a Manner, that the Faces and Flanks of the Cavalier are parallel to the Faces and Flanks of the Bastion; as C. The Advantages that proceed from this Disposition, are, that the Enemy being got upon the opposite Counterscarp, will be troubled to lodge his Cannon there, by reason of the Cannon upon the Flank, and upon the Cavalier; which playing without ceasing, will dismount the Enemy's Artillery, and hinders him from raising Shoulders to secure himself: Besides that, the Breach of the opposite Face is much better defended, and the Field better scoured. But one would think they might enjoy all these Advantages without possessing the Platform of the Bastion; and by that Means deprive themselves of the Advantage of making Entrenchments; which favour the Defence of Assaults. Besides that, these Cavaliers are of no use for the Defence of the Breach made in the Bastions where they

they stand. And there is this moreover, That the Besieger may at the same Time, with a Mine, carry away a part of this Cavalier with the Face of the Bastion. And lastly, It is for the Defendants to deprive themselves of several Advantages; which we shall observe in the following Method, and which has all the Advantages of the preceding Situations, without being obnoxious to their Inconveniencies. But before we speak of this Cavalier, observe the Construction of it; of which we have set down the Advantages and Disadvantages.

1. If the Bastion is empty, it ought to be filled up, till it come to be as high as the Platform.

2. Which being done, raise that which was empty upon the Platform, from nine to ten Feet.

3. Having levelled that Height toward the Top, you shall draw the Base of the Parapet of three Fathoms, which ought not to be raised above six Feet; because the Cannon are not to be placed higher; for that being higher, they would require a Battery to be raised on Purpose.

IV. Lastly, There are others that place the Cavalier within the Bastion, of a circular Figure; disposing it thus:

1. They prolong a Line of Defence in the Body of the Place, till it cut the Radius from the Center at the Point A.

2. They divide the Distance between this Point A, and that of the Gorge B, into two equal Parts; as, AC, CB.

3. From the Point C, they draw a Circle, which makes the Base of the Cavalier.

4. They

4. They raise this Place from nine to ten Feet above the Platform of the Bastion.

5. They allow this Cavalier a Parapet three Fathoms wide, and one high.

5. The best Lining of this Cavalier, is with Turf; for if it were of Mason's Work, the Bricks and Stones, which will be shattered from it, would annoy those that defend the Rampart.

It is objected against this, That they do not leave room enough between the Foot of the Cavalier, and the Parapet of the Flank, for the free Passage of the Men that are to defend the Breach, and to traverse the Guns, which are upon the Flanks of the Bastion, because their Carriages being long, they will take up a great deal of Ground.

But it is answered, That this Cavalier being distant, at least, five Fathoms from the Parapet, this Passage seems to be more than sufficient to communicate between the Rampart and the Bastion, in respect of the Place of the Cannon; and in regard the Largeness of the Base of the Cavalier may be lessened, if it be found to incommode the Passage, we must confess, there is room enough, not only when the Cannon are mounted upon small Carriages, but that when they are mounted upon their usual Carriages, these Cavaliers bear them above all others.

C H A P. XV.

Of Counterscarps.

IT may be said, That Counterscarps cut in the Rock, are the best; for, besides the Difficulty
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of opening them, to descend into the Moat, they need no Talus or Sloping, as being sufficient to support themselves.

Those that are lined are to be preferred before those that are not, by reason of their Durance; though it may be feared, That the Enemy will make use of that Lining to secure himself, and make a Gallery all along with Embrasures, to play upon those that defend the Moat: But this Reason signifies little; for when a Moat is full of Water, the Counterscarp ought to be lined of Necessity; otherwise the Earth being moistened by the Water, tumbles easily down; but if the Moat be dry, a Lining is not so absolutely necessary. The Sloping ought to be allowed after such a Manner, that if the Enemy should enter with the Soldiers of the Garrison, upon some hot Occasion, he could not easily get out again. That part of the Counterscarp which is before the Point of the Bastion, ought to be rounded, to gain the Space above the Covert-way; provided you can keep there a Body of your Men, to be in a Condition to sustain an Assault.

C H A P. XVI.

Of the Streets, Places of Arms, Corps de Gard, and Magazines.

HAVING shewed, Book 3. Chap. XX. how to make the Streets in a Fortrefs, we shall first speak of the Place of Arms. The grand Place of Arms ought to be in the middle of the Fort; the Construction of which is contained in
Chap.

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Chap. XX. Sect. 3. The lesser Places of Arms ought to be on the Side of the Bastions; the Bigness of which ought to be proportioned so, as to hold two hundred Men for every Bastion; or five hundred, if they are to sustain a Siege: And in regard that every Man marching in Battalia, takes up no more than three Feet in Rank, and seven in File, it is easy to know how many Men will serve for every Fortrefs, and how large the Places of Arms ought to be.

The most numerous Corps de Gard ought to be in those Parts where the most numerous Guard mounts. There must be one or two Chimnies at least; and a little Theatre of Wood all along, about three Feet high from the Ground, and seven or eight Feet broad, for the Soldiers to lie upon. The other Corps de Gard, built after the same Manner, are to be placed near the Gates, or Passages.

In regard that there is always Occasion for Ammunition, that is, for Powder and Ball, for the Soldiers that are upon the Ramparts, there must be Arsenals near at hand. But great Care must be taken to put the Powder where it may not take Wet; much more, where it may be in Danger of being fired.

The Magazines of Hay and Provender for the Cavalry, ought to be near the Stables where the Horses stand. The others must be built in the most secure Parts of the Garrison.

In regard the Soldiers, as well Foot as Horse, are often lodged in Hutts; these Hutts are to be set up near the Rampart, to the end, that in case

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 of Necessity, they may be ready upon the Rampart, to defend the Place. To which Purpose, the Town is to furnish them with Beds, Tables, Benches, and Hangings, for the Officers Chambers, under whose Government the Soldiers are to serve; their Presence being necessary, to keep them in order, and from being injurious to the People of the Town. Every Hutt ought to be so large as to hold four Soldiers. Every Captain ought to have a particular Chamber, and another for two Lieutenants. These Hutts ought to be eighteen Fathoms long, and seven and a half broad, and four Fathoms high, though there are some that are higher.

C H A P. XVII.

Of the Gates.

A GATE, if it be well placed, ought to be in the middle of the Courtain; because that in that Part it is defended with two Flanks, which lie on both the Extremities of it. The Gate cannot be too well secured, because that there Surprizes are generally most attempted; whether by petarding, or by Intelligence from the Garrison. Some place the Gates in the Flanks, because, say they, the Sallies are by that Means more private, and for that those Gates look athwart the opposite Flank. But, besides that, being so placed, they very much weaken the Flanks, which are almost the chief Strength of the Place, and hinder by that Means the opposite Face to that Flank from being

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Book IV. *A Treatise of Fortification.* 165

being well defended ; they also hinder the use of the retired Flanks and the Tenails.

As for those that are placed in the Faces of the Bastions, they are worse disposed ; not only because it is a kind of a Breach already made, but because they are not flanked, but by a part at a great Distance : The Sallies also are too much in View ; nor can they be secured by any Work, but such a one as is not flanked ; which is a very great Defect.

The Wideness of the Gates ought to be from fourteen to sixteen Feet. The Height from fifteen to seventeen. The Thickness like to that of the Rampart of the Wall. They ought to be all vaulted, or else the greatest Part of them, and well guarded.

There must be great Stones laid at the Extremities of the Gates, to hinder the Carts from spoiling the Wall. The Wood of the Gate ought to be of good Oak, joined and fastened with good Nails and strong Bars of Iron.

C H A P. XVIII.

Of Back-Doors, or Sally-Ports, and Draw-Bridges.

TO sally out of the False-Brays, Sally-Ports are made of such a Wideness that the Cannon may pass through them ; that is to say, they ought to be from seven to eight Feet wide, and from eight to nine Feet high.

The Draw-Bridges are made after several Fashions ; but the most usual are made with Pliers. Their Length and their Wideness ought to be proportionable to their Borders or Frame of the

Gate which are to hold them, being drawn up. The Arms ought to be from eight to nine Inches thick, as also the Beam that joins them.

The Shoulder to which the Arms are annexed, and upon which they are to turn, ought to be from fourteen to sixteen Inches in Diameter. The Extremities being bound about with two good Circles of Iron, you must drive through the Center two Iron Pins, a Foot long, and two or three Inches in Diameter, to the end that it may the more easily move upon a strong Band of crooked Iron, which is to be joined to the Threshold and Jaumbs, or Side-Posts, of the Gate. The Pliers are to be twice the Height of the Gate, at least, and one Foot in Diameter. The inner Square must be traversed with a St. *Andrew's* Cross, which will serve for a Counterpoise. The Chains are to be of Brass, to the end that the Bridge may never be let down without making a Noise.

C H A P. XIX.

Of Bridges.

THE Bridges of a Town are to be from fourteen to fifteen Feet wide; lower than the Field, and somewhat round. When they are streight and even, they ought to be made a little higher in the Middle than toward the Extremities, that the Foot of the Gate may not be discovered. Though the Supporters of Bridges may be of Stone, nevertheless they will be better, if their Planks and Rails are of Wood, that they may be the more easily cut down upon Occasion. When there is

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no Half-Moon before a Gate, it is certain that the Bridge which crosses the Moat ought to be the wider, because there must be a good Corps de Gard upon it, and a Draw-Bridge. But if there be a Half-Moon, some turn aside the Way all along the Gorge of the Half-Moon above the Counterscarp, and make a Corps de Gard and a Palisadoe, which hinders the Entrance of the Enemy: Others carry the Way through the Extremities of the Face. And a good Corps de Gard ought to be set at the end of the Bridge with a Portcullis.



BOOK V.

CHAP. I.

IN regard that Fortification is either continual, or transitory, we shall now speak of the latter, as having given full Instructions for the first : Let us begin with a Redoubt.

Of the raising a Redoubt.

1. Make a Rectangle Square, each Side of which contains from twelve to twenty Fathoms.
2. Within this Square draw the Base of the Rampart three Fathoms large ; and that of the Parapet from nine to ten Feet. The Height of the Rampart above the Level of the Field ought to be three Feet ; and that of the Parapet above the Platform of the Rampart, of five, as is usual : Or of seven, when there are two Steps or Banquets : Though sometimes they raise the Rampart a little higher, as Necessity requires.
3. About the Rampart toward the Field draw another Parallel three Feet wide, which is called the Berme.
1. Above the Berme make a Moat of four Fathoms, with a Rounding before the Points of the exterior Sides : The Depth of the Moat ought to be about eight or ten Feet.

5. The

5. The Bridge for Entrance into the Redoubt ought to be ten or twelve Feet broad, when you would bring the Cannon into it; otherwise five or six Feet of Breadth will suffice. See the Plate Q, Fig. XXVIII. in Chap. XIV. Lib. IV.

C H A P. II.

Of the Half Redoubt.

1. **D**RAW a Line of seventeen Fathoms, as A B.
 2. Make an Iſosceles Triangle of twelve Fathoms from the Points A B, as A C, C B, and join A C and C B together.
 3. Prolong the Line A B, and place upon the Prolongation on each Side, eight Fathoms and three Feet, as A D, B E.
 4. All the reſt is done, as in the precedent Work. See the Plate R, Fig. XXIX.
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C H A P. III.

Of the Star-Square.

1. **M**AKE a Square, each Side containing twelve Fathoms in Length, as A B C D.
2. From the Middle of each exterior Side, draw a Perpendicular of two Fathoms, as D E F G; and afterwards draw A B in the Point E, B C in the Point F, D C in the Point G, and D A in the Point H. The reſt is done, as in the Redoubt. See the Plate R, Fig. XXX.

C H A P.

C H A P. IV.

Of the Star-Pentagon.

1. **D**R A W a Circle of twenty-seven Fathoms, and divide it into five equal Parts, with thirty-one Fathoms five Feet, as A, B, C, D, E.
2. Join the Sides together by streight Lines, and divide each into two equal Parts; let fall from the Middle of them the Perpendiculars of five Fathoms, F, G, H, I, L.
3. Draw from the Points A, B, C, D, E, streight Lines into the Points F, G, H, I, L.
4. The Base of the Rampart is six Fathoms. That of the Parapet two. The Berme three Feet. And the Breadth of the Moat five Fathoms. See Fig. XXXI. of the Plate R.

C H A P. V.

Of the Star-Hexagon.

1. **D**R A W a Circle of twelve Fathoms, and divide it into twelve equal Parts, as A B C D E F.
2. Join these Points together by streight Lines, and divide each into two equal Parts, then let fall from the Middle a Perpendicular of two Fathoms, as G H, I K, M N.
3. Join these Points with the six first, as in the preceding Works.
4. Draw the Base of the Rampart of three Fathoms; that of the Parapet nine Feet; the Berme three Feet; and the Moat of five Fathoms. See the Plate R, Fig. XXXII.

C H A P.

C H A P. VI.

Of the Triangle of Half Bastions.

1. **M**AKE an equilateral Triangle, of which each Side contains twenty-four Fathoms, as ABC.

2. Prolong the Side AB, and place upon the Prolongation eight Fathoms, as BE. Then also prolong the other Side BC, and place upon the Prolongation eight Fathoms CF. Lastly, Place upon that of the Line CA the same Distance, as AG.

3. For the Demi-Gorges take the same Distance, as BH, CI, and AL, and then raise Perpendiculars upon the Points H, I, L. And for the Flanks a Length of four Fathoms HM, IN, and LO. This done, join the Points ME, OG, and NF together, to gain the Faces: And thus you have the Design of your Triangle.

4. The Base of the Rampart takes up three Fathoms and a half. The Base of the Parapet one Fathom four Feet. The Berme three Feet. The Moat five Fathoms. It ought to be parallel to the Flanks, and round before the Points of the Half Bastions. See the Plate R, Fig. XXXIII.

C H A P. VII.

Of the Square of the Half Bastions.

1. **M**AKE a Square, each Side containing twenty-four Fathoms, as A, B, C, D.

2. Prolong

2. Prolong the Line BA, and upon the Prolongation place eight Fathoms, as AE: Then make that of the Line AD, of the same Distance as DF. This done, prolong also the Line DC of eight Fathoms, as CG: Then make the latter CB of the same Length as BH.

3. For the Demi-Gorges, take also eight Fathoms BM, AI, DK, and CL.

4. Raise upon the Points I, K, L, M, the Flanks perpendicularly; the Length of which is four Fathoms, as IO, KP, LQ, and MN.

5. Draw the Faces, joining together NHQG PF, and OE.

6. Having the Draught of the Square, let the rest be as in the preceding Triangle. See the Plate S, Fig. 34.

C H A P. VIII.

Of the Square of entire Bastions.

1. **M**AKE a Square, each Side containing thirty-one Fathoms, as A, B, C, D.

2. From the Middle of each Side, let fall a Perpendicular of four Fathoms, as E, F, G, H.

3. Draw the Faces after *Vauban's* Manner, and add thereto ten Fathoms.

4. Take the Extremities of the two Faces; and from one of them, let the Compass fall upon the Complement of the other; and in that Part where it touches the Complement, join the same Point to the Extremity of the Face, which is the nearest to it, for the Flank. That done, draw the Courtain.

5. The

5. The Base of the Rampart contains five Fathoms, that of the Parapet two Fathoms three Feet, the Berme three Feet, and the Breadth of the Moat six Fathoms. See the Plate S, Figure 35.

CHAP. IX.

Of a Pentagon with entire Bastions.

1. **D**RAW a Circle of twenty-seven Fathoms, and divide it into five equal Parts, with one Distance of thirty-one Fathoms five Feet, as A, B, C, D, E; and join the Points together by right Lines.

2. From the Middle of each Side let fall a Perpendicular of five Fathoms, and draw the Faces as usually, after *Vauban's* Manner; the Length of which must be ten Fathoms.

3. The Flank is made, by setting the two Points of the Compass upon the two Extremities of the Faces; of which the one falls upon the Complement of the Line of Defence, as has been said in the preceding Chapter: This done, join the two Flanks together for the Courtain.

4. The Base of the Rampart takes up five Fathoms.

The Base of the Parapet two Fathoms three Feet.

5. The Berme of three Feet: The Breadth of the Moat six Fathoms. See the Plate S, Figure 36.

C H A P. X.

Of the Half-Hexagon with entire Bastions.

1. **D**R A W a Circle of twenty-eight Fathoms, four Feet, and divide it with the same Distance into six equal Parts, of which you shall take three for your temporary Work.

2. Divide into two equal Parts each of the three Sides, and from the Middle let fall a Perpendicular of five Fathoms.

3. Draw the Faces as usually, of which let the Length be eight Fathoms.

4. The Flank and Courtain are made, as in the preceding Works.

5. The Base of the Rampart contains six Fathoms. The Base of the Parapet two Fathoms four Feet. The Berme three Feet. The Breadth of the Moat six Fathoms. See the Plate S, Fig. 37.

A R E M A R K.

In regard this Fortification is only for present use; and because for that Reason it is sometimes stronger than the other, the Draught and Proportion of it could not be ascertained, as in a continual regular Fortification. Only we may say, that most frequently the Rampart of these sorts of Forts is raised like those of Redoubts. See the first Chapter, Lib. V.

C H A P. XI.

Of the Maxims of irregular Fortification.

IRregular Fortification is that, of which all the Sides and Angles are not equal one to another. The Original of this Fortification proceeds from ancient Towns and Cities; which were built after no regular Figure, and yet required to be encompassed with Walls and Bastions, to defend themselves against the Assaults of their Enemies. But because it was impossible to fortify those irregular Places, and make them, in respect of their Duration, equal to regular Places, there are certain Maxims, according to which they may be environed with a passable Fortification. For Example:

1. Every irregular Fortification ought to be made according to the Maxims of the regular as near as may be.

2. The most irregular Forts are the best, provided they be not too easy of Access.

3. Entire Bastions are to be preferred as much as may be, before Half-Bastions.

4. No Face ought to exceed sixty Fathoms.

5. No Flank ought to be less than sixteen Fathoms, if it be possible.

Therefore when you are to make an irregular Fortification, you must consider, 1. The Quality of the Situation. 2. The Time allowed to make the Work. 3. The Number of Men which are to be put in to defend it. 4. The Number of Workmen. 5. The Victuals. After all you must draw the Plane, and fortify it after the following Manner.

C H A P.

C H A P. XII.

*The Manner of fortifying an irregular Place,
where there is nothing but the Field.*

1. **H**AVING the Plane of the irregular Place, divide each exterior Side into two equal Parts, and from the Middle let fall a Perpendicular.
2. Upon each exterior Side draw an Iſosceles Triangles of 480 Fathoms.
3. Place upon these Triangles all the Parts and Distances which you make use of in a regular Fortification, and take the Distances across to put them upon the Parts of your irregular Plane. For Example: If an irregular Pentagon be to be fortified, I take 180 Fathoms, and I make upon each exterior Side an Iſosceles Triangle, A B C. Then I take twenty-five Fathoms, which I put upon the Triangle A B C, as C D E; of which the Length D E shall be the true Length for the Perpendicular of the Line A B: Which done, I put fifty Fathoms upon the same Triangle, as C F G, the Length F G, shall be the just Distance for the Face of my Work. After this, I put again thirty-eight Fathoms three Feet upon the Triangle; and the Distance taken across H I, will give me the true Length for the Complement of the Line of Defence. Lastly, I join the Flanks and the Courtains together, as in a regular. After which I divide the Flank into three equal Parts; I draw the Brisure as usually, and retain one of the three Parts of the divided Flank for the Orillon, and the two others for the hollow Tower. See the Plate T, Fig. 38.

C H A P.

C H A P. XIII.

Of the Body of the Place in an irregular Fortification.

THE Body of the Place make thus :

1. Take eleven Fathoms for the Base of the Rampart, and put them upon each Triangle. The Length across will always give you the true Breadth of the Base of the Rampart.

2. Take three Fathoms, and bring them round about the Place, without putting them upon the Triangles. Draw the Banquets as usually.

3. Take twenty Fathoms for the Breadth of the Moat, and put them upon all the Triangles, the Distance taken across will be the true Breadth of the Moat for every Side. The Manner of making this Fortification is the same with that of the Regular. See the Plate T, Fig. 38.

C H A P. XIV.

To make a Half-Moon before these Fortifications.

BE sure to see whether the Length of the Courtain exceeds 100 Fathoms or no. If it be from 100 to 140 Fathoms, take fifty Fathoms for the Capital of the Half-Moon or Ravelin. But if it be larger than 140 Fathoms, erect before the Ravelin another Work, whether a Horn or Crown-work. If the Courtain be not longer than 100 Fathoms, take the half of the Courtain with the Brisure, for the Capital of the Ravelin, and the rest is done as in a regular Fortification. For

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the

the Base of the Rampart is eight Fathoms. That of the Parapet three. The Breadth of the Moat twelve. These Distances are to be put upon the Triangles, before the exterior Sides of which you intend to place the Ravelin, and afterwards taken across.

C H A P. XV.

To set other exterior Works before the same Fortifications.

IF an exterior Polygon exceeds 120 Fathoms, and that you have still room to erect a good Work before it, whether Horn or Crown-Work; as you may see in Fig. 39. which is a Crown-Work made according to the Rules of Chap. 10. Lib. 3. The Parts of it ought all to be marked upon the Triangle.

A B, Is the Basis of the Rampart of the Ravelin, and the Horn-work.

C D, Is the Basis of the Rampart of the Body of the Place.

E F, Is the Breadth of the Moat belonging to the Ravelin and Horn-work.

G H, Is the Perpendicular of the Horn-work, from the End of which are drawn the Faces.

I K, Is the Breadth of the Moat belonging to the Body of the Place.

23, Is the Perpendicular of the Body of the Place.

L M, Is the Face of the Horn-work.

N O, The Complement of the Line of Defence to the Body of the Place.

P Q, The Face of the Body of the Place.

R S, The Capital of the Horn-work.

T V, The

TV, The Distance which joins the Point of the Capital to the Horn-work.

WX, Are the Wings of the Horn-work.

C H A P. XVI.

How to fortify an irregular Place already built.

TO avoid much Labour, you must fortify the Parts of an old Fortification, and finish them, in the same Manner as they were begun, unless they are gone utterly to Decay; and then you may make what Alterations you please. To the end therefore, that Money may be laid out to good Purpose, when the Flanks are repaired, they must allow an Overture of 100 Degrees. If the Faces are tolerable, let them alone as they are, to avoid the vast Expence in making others. Whence it comes to pass, that there is no ancient Place which is fortified after the *French* Manner, because the Engineers have been always forced to labour upon *Dutch* Fortifications. As for the Rampart and Parapet, they may be better fortified whatever Face they have. But to come to the Thing itself, let us observe the following Rules:

I. The exterior Side, the Length of which is from sixty to eighty Fathoms, requires a Demi-Gorge from fourteen to fifteen Fathoms, and a Flank of fifteen Fathoms.

II. If the exterior Side takes up from 80 to 140 Fathoms, it is to be divided into five equal Parts; of which one is retained for the Demi-Gorge. The

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Flank

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 Flank changes according to the Variety of the
 Sides. For Example : If the exterior Side is of
 80 Fathoms, the Flank shall be of 16.

If of {	90	} the Flank of {	17.
	100		18.
	105		19.
	110		20.
	115		21.
	120		22.
	125		23.
	130		24.
	135		25.
	140		25 Fathoms 3 Feet.

This being well understood, it will not be difficult to reduce it into Practice. Suppose the Pentagon following, of which the Side AB is 130 Fathoms, BC 124, CD 130, DE 113 Fathoms three Feet, EA 146 Fathoms, and that you design to fortify it.

1. Allow the fifth Part of each exterior Side for the Demi-Gorges, as AF, BG, CI, CK, DL, DM, EN, EO, and AP.

2. Raise upon FG, HI, KL, MN, OP, Perpendiculars for the Flanks, in case you cannot allow them an Overture of 100 Degrees ; the Length of which must be proportionable to the Length of the Sides. For Example : The Flanks FG shall have 24 Fathoms, HI 22, KL 24, MN 20, EA 25 Fathoms and three Feet.

3. In drawing the Line of Defence, you will have the Faces at the same Time.

4. The Base of the Rampart takes up eleven Fathoms. That of the Parapet three. The Breadth
 of

of the Moat twenty Fathoms. The Covert-way and the Glacis, are made as is usual. See the Plate W, Fig. 40.

OBSERVATION.

The Flank is left after the *Holland* Manner; that is to say, without either Orillon or hollow Tower, to avoid overmuch Expence.

III. If the exterior Side be from 140 to 170 Fathoms, the Flanks are allowed the following Length:

If it be 145, allow the Flank 25 Fathoms 3 Feet.

If 150, to the Flank 26 Fathoms.

If 155, to the Flank 26 Fathoms 3 Feet.

If 160, to the Flank 27 Fathom.

IV. The exterior Side surpassing the Length of 160 Fathoms, to 280, is looked upon then as if it had two Sides; that is to say, that besides the Bastions which are placed upon the Angles there should be a Platform in the Middle; as you see in Fig. 41. where the Side A B is 200 Fathoms, and the Construction of it thus:

1. Divide the Side A B into two equal Parts; as, A C, C B.

2. Divide either the Distance A C, or the other C B, into five equal Parts, to give one of them to the Demi-Gorge; as, A D, E B, C F, C G.

3. Raise upon D G, F F, the Flanks of an Overture of 100 Degrees, the Length of which shall be the Demi-Gorge.

4. From the Point C, draw the Capital, which takes up the Length of the entire Gorge; as, C H.

N 3

5. Join

5. Join the Extremities of the Flanks, and the Point H together, by a right Line, to gain the Faces. See the Plate W, Fig. 41.

OBSERVATION.

These forts of Bastions are perfectly well defended; for the Flanks of the neighbouring Bastions play backwards upon their Faces; besides that, almost all the Courtain serves them instead of a second Flank, and very much augments their Defence.

V. The exterior Side surpassing 280 Fathoms, two flat Bastions are placed there; holding this for a Maxim, That the greatest Side ought to be 140 Fathoms.

C H A P. XVII.

How to fortify an acute Angle.

IF you find by chance an acute Angle with the Circuit of a Place which is to be fortified, since it is impossible to repair this Defect; because you are obliged to make use of the old Ramparts; you are only to put upon this Angle a tenail Bastion; which is thus erected:

1. Having made the Flanks, draw the Faces as the Line of Defence requires; but in regard they would be excessive long, and would form too acute a Point, that is corrected by putting forty Fathoms from the Top of the Flank above the Face, as A B, C D.

2. Join

2. Join BD together by a right Line, and then divide that Line into two equal Parts, BE, ED; and from the Middle of the same Line, let fall a Perpendicular, which has for its Length the third Part of the same Line; as, EF.

3. Draw the Points BD, in the Point F, by right Lines, and your Bastion is made. Oft-times they erect little Ravelins before these sorts of Bastions: But to say the Truth, this Work is not worth any Thing; nor is it ever to be made use of, but upon Necessity. But you shall meet with it in some Places; as, at *Geneva*, and *Charlemont*. This small Ravelin must not be separated from the Bastion, but by a small Moat of five or six Fathoms. Moreover, there is no Necessity for its having Ramparts, but only a good Parapet Cannon Proof. There are several other Ways of fortifying an acute Angle; but which are of no more Value than this. Therefore we must endeavour to avoid them; for notwithstanding all the Care a Man can take to fortify this Angle, it will be very defective. See the Plate W, Fig. 42.

C H A P. XVIII.

How to fortify a re-entring Angle.

THERE are few irregular Places, of which the old Enclosure does not form a re-entring Angle; which is almost always secure, as being seen from several Parts. But usually it is accompanied with one Defect, that it almost always forms

the two saliant Angles which are next it, too acute. It is true, that if these saliant Angles were not too acute, your Firing-place would be very great, from a Work made upon the re-entring Angle, to defend the Bastions that are in Sight of it; nor is it always a Fault to have these re-entring Angles, which are thus fortified.

If the Angle be not very far sunk in, and very obtuse, as A, it is thus to be fortified:

1. Place on each Side of the Angle great Demi-Gorges, in case the Sides will permit it, and raise perpendicular Flanks, as large as you can.

2. Join their Extremities together, by a right Line; which you shall divide into two equal Parts; and from the Middle raise a Perpendicular, containing the Moiety of the said Line.

3. Draw the Extremities of the Flanks toward the capital Line of that Perpendicular, and your re-entring Angle will be fortified. See Plate X, Fig. 43.

If the re-entring Angle be somewhat obtuse, or streight, in this Case, having taken good Demi-Gorges from every Side of the Angle, the Flanks are there to be raised; the meeting of which forms the saliant Angle B; which is capable to defend the neighbouring Bastions. See Plate X, Fig. 44.



C H A P. XIX.

Of the Artillery.

HAVING given some Account of irregular Fortification, reserving to ourselves another Time to speak more of it; we shall only observe what sort of Artillery they have in *France*. There is, 1. The Cannon, which is called the Battering Piece. 2. The Culverin. 3. The Falcon. 4. The Saker. 5. The Petard. 6. The small Petard. The Battering Piece is ten Feet long, the Bullet about six Inches Diameter, and weighs thirty-three Pounds, requiring two Pounds of Powder, at least, to charge it; and it carries directly forward 360 Fathoms. At the Distance of 100 Fathoms, it pierces two Fathoms of closed Earth. If it be not well settled, it pierces two Fathoms and a half; and if the Earth be poor and hungry, it pierces four Fathoms. You may discharge it eighty Times in a Day. The *Dutch* Cannon flings a Bullet of forty-eight Pounds, 400 Feet Distance, and pierces a Rampart of good and well closed Earth twenty Feet deep. A half Piece of Battery carries a Bullet of twenty-four Pounds, at 300 Feet Distance, and enters twelve Feet of good Earth. The Falcon carries a twelve Pounder 200 Feet off, and enters seven Feet into a good Parapet.

A small Petard cannot break a double Gate well barred.

A great Petard, fixed to a weak Gate, usually makes no more than a Hole; and the greatest Execution it can produce, is to break the fore Part of it.

There

There is nothing can stop the Execution of Mines, as they make them at present ; nevertheless there must be a Proportion between the Petards, the Mines, &c. and the Powder.

Lastly, a Musquet carries 120 Fathoms, and if double charged 150, though it will kill a Man above 300 Paces. Discharged very near, it will pierce two Flanks two Fingers thick ; but discharged at fifty Paces, it enters according to the Substance of the Body it meets with. We shall insist no longer on these Things at this Time ; intending to speak more amply of them in another Treatise, where we shall shew the Manner how to attack a Place.



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OF
MILITARY ORDERS.

OR, THE
Embatteling and encamping of
Soldiers.

Of embatteling of Soldiers.

Battails are considered either in respect of the Number of Men, or in respect of the Form of the Ground. In respect of the Number of Men, it is either a *Square Battail*, a *Double Battail*, a *Battail of the Grand Front*, or a *Battail of any Proportion*, of the Number in *Rank*, to the Number in *File*. In respect of the Form of the Ground, the *Battail* is either a *geometrical Square* of Ground, or a *long Square* of Ground. For the Distance or Order of Soldiers martialled in Array, it is distinguished either into *open Order*, which is when the Centers of their Places are seven Feet distant in Rank and File; or *close Order*, which is when the Centers of their Places are 1 Foot $\frac{1}{2}$ distant both in Rank and File, or else three Feet $\frac{1}{2}$ in Rank, and seven Feet in File.

P R O P.

P R O P. I.

To Order any Number of Soldiers into a Square Battail.

Suppose it were required to martial into a Square Battail 16129 Men; to do this *extraēt* the Square Root of 16129, it gives 127, which is the Number of Men you must place both in Rank and File.

P R O P. II.

To order any Number of Soldiers into a double Battail.

Admit 16928 Soldiers were to be martialled in a double Battail, *extraēt* the Square Root of half the Number of Men, that is of 8464 it gives 92, and therefore, I say, that 92 Men must be placed in File, and 184 in Rank, which orders such a Number of Men in double Battail.

P R O P. III.

To order any Number of Soldiers into a Battail of the Grand Front.

Admit 16900 Soldiers were to be martialled in a Battail of the Grand Front; *that is*, Quadruple; or so that the Rank may be four Times the File. *Extraēt* the Square Root of $\frac{1}{4}$ the Number of Men, that is, of 4225, the Square Root of which is 65, the Number that must be placed in File, and four Times 65, which is 260, is the Number to be placed in Rank, to form a Battail of the Grand Front.

P R O P.

P R O P. IV.

Any Number of Men, with their Distance in Rank and File, being propounded, to order them into a Square Battail of Ground.

Admit 2500 Soldiers were to be martialled in a Square Battail of Ground, in such Sort that their Distance in File should be seven Feet, and in Rank three Feet, it is required to know how many Men must be placed in Rank, and how many in File. To draw up 2500 into a Square Battail of the Ground, say, as 7 to 3, so is 2500 to 1071, &c. whose Square Root is 32, the Number of Men to be placed in File. Now to find how many Men are to be placed in Rank, divide 2500 by 32, the Quotient is 78, which are the Number of Men to be placed in Rank, and four Men over and above to be disposed of.

P R O P. V.

Any Number of Soldiers propounded, to order them in Rank and File, according to the Reason of any two Numbers given.

Suppose 6400 Soldiers are to be martialled into Array, in such Order that the Number of Men placed in File, shall bear such Proportion of Men in Rank, as 7 to 13, say, as 7 to 13, so is 6400 to 11885, &c. whose Square Root is 109 *prope*, the Number of Men to be placed in Rank; by which divide 6400 it produces 58, &c. the Number of Men to be placed in File, and 78 Men to be employed elsewhere.

Of

Of quartering and encamping of Soldiers.

In quartering and encamping of Soldiers, it is requisite the *Quarter-Master-General*, and all other under Quarter-Masters, should be skilled in Foot Measure, that so they may the better lay out their Quarters as directed.

The common Allowance for the Depth of Ground, that a Regiment of Horse or Foot will take up, is proportioned after this Manner: The Wideness must be answerable to the Number of Men; suppose 200 Feet in Length be allowed for the Hutts for the common Soldiers, and 100 Feet for the Commanders and Suttlers Tents before them, each Hutt is eight Feet square, and holds two Soldiers; the Distance betwixt each Hutt is two Feet, and therefore in the 200 Feet may stand twenty Hutts, the Walk betwixt each Row of Hutts may be eight Feet, that is Hutt and Space left will be sixteen Feet one Way, and ten the other Way; so that 200 Feet in Length, and sixteen Feet in Breadth, or 3200 Square Feet, will serve forty Men, and for the 100 Feet more for the Officers there will be 1600 Feet; in all, 4800 Square Feet. Now for 1000 Men, there must be twenty-five Rows of Hutts; so that a Regiment of Foot, containing 1000 Men, (besides Officers and Suttlers) will take up 80000 Square Feet, and the Officers and Suttlers 40000 Square Feet more; that is, the whole Regiment, including Officers and Suttlers, will take up 120000 Square Feet, which is two Acres three Roods: But because of Ways, there may be allowed three Acres of Ground for every Regiment, which may be 350 Feet deep, and 370 Feet wide,

or near 360 Feet square. Now if 1000 Men, Officers, Suttlers, Highways, and all take up a Square of 360 Feet, how many Feet shall the Side of a Square be wherein 10000 Men with their Officers and Suttlers may be encamped? Say as 1000 to 10000, so is the Square of 360, viz. 129600 to 1296000, the Square-Root of which is 1138 Feet, which Square contains very near thirty Acres of Ground.

For the Quartering of Horse, you must keep the same Depth of 300 Feet, as you did for the Foot, and take 200 Feet for the Huts; the Hutt for one Horse must be four Feet wide and ten Feet deep, so that twelve Horses may stand together in a Hutt forty-eight Feet long and ten Feet deep, over and above there must be six Feet left for a Street, so the whole Depth is sixteen Feet; the Huts for the Troops will be six for twelve Troops; now conceive a Regiment to consist of eight Troops, fifty to a Troop, it will take up, leaving twenty Feet, Streets and Cross-ways, very near as much Ground as a Regiment of Foot, Ways and all must be allowed three Acres, that is, near 360 Feet Square, so that ten Regiments of Horse will take up thirty Acres of Ground; moreover it will be needful, and you may very well allow as much Ground as both Horse and Foot will take up, for the Train of Artillery, Victuallers, and Parade Places. From these Considerations, the young Beginners, nay, even the practised Soldiers, may receive Help, and thereby be enabled to encamp an Army, if required.

O F
G U N N E R Y.

*The Names of the chiefest Members of a Piece
of Ordnance.*

A CANNON is a long round Body either of Brass or Iron, formed and made hollow by Art and Proportion; its use is to offend afar off, with a Ball of Iron, Stone, or any artificial Substance, charged with Gun-powder in its Cylindrick Cavity, which being filled, in an Instant performs its Effect. This Machine was invented by an *Englishman*, and first put in Practice by the *Venetians* against the *Genoeses* at *Chiezza*, Anno 1376.

The *Superficies* of the Metal is the outside round about the Piece.

The *Body* is the Substance of the whole Mass of Metal.

The *Chase* or *Soul* is the Cavity of the Piece in which they put the Charge.

The *Muzzel* is the Extremity of the Chase, at which you load and unload the Piece.

The *Calibre* is the Diameter of the Muzzel or Mouth, as A B.

The *Touch-hole* is that little Vent which passeth from the Convex Superficies to the Cavity of the Piece; it is made to give fire to the Powder within, as C; that which encloseth the Extremity of the Chase, about the Touch-hole, is the Breech or Coyle.

The *Cascabel* is the Pammel at the Breech or Coyle, as D.

The *Trunnions* are Pieces of Metal fixed unto the exterior Superficies of the Gun, and are those on which it moves in the Carriage, as E E.

Malignions or *Dolphins* are two Handles which of late are fixed upon the Back of the Piece near upon the Center of Gravity thereof. Their use is to mount and dismount the Piece.

The *Body of the Piece* is that which is comprehended betwixt the Center of the Trunnions and the Cascabel.

The *Vacan Cylinder* is comprehended betwixt the Center of the Trunnions and the Muzzel, as E B.

The *Freez* or *Muzzel Ring* is that thick Cornice which encompasseth the Convex Superficies of the Piece, as I; the *base Ring* is K L G; the *reinforced Ring* is M M; the *Trunnion Ring* is N N; and the *Cornish Ring* is O O.

The *Line of the Cylinder* is a Line imagined to be drawn along the Chase, parallel to the middle of the Chase, as X Z.

The *Line of Metal* is a Line touching the Top of the Cornice of the Base and Muzzel Rings, such is the Line K E if it were drawn.

The *Dispart Line* of the Piece is the Difference betwixt the Semi-Diameter of the Muzzel and Base Ring, as the Line I H.

The *Vent of the Piece* is the Difference betwixt the Diameter of the Shot and Mouth of the Piece.

The *Chamber* or *charged Cylinder* is that part of the Chase toward the Touch-hole, equally large, nor narrower in one Place than in another, being that which contains the Powder and Ball.

A *Mortar-piece* is a short Piece, with which they shoot *Bombs*, *Granado-Shells*, *Stone-Balls*, &c. not by a right Line, or one nearly parallel to the Horizon; but by a Curve from on high, so that it may fall where it is desired. Now this *Mortar* is placed in all respects as you see in Fig. 93. Plate IV.

Where A signifies the Carriage, B the Mortar, C the Course the Shot flies, and D the Place on which it falls.

Bombs are great hollow Balls of Iron or Brass, in which are put fine sifted Gun-Powder, which by a Fuse, they proportion to them due Fire, that so they may break as soon as they fall amongst the Enemy. These *Fuses* are small Trunks of Wood, Tin, or Iron, filled with a Composition prepared for that Purpose.

Granadoes are of the same Form with *Bombs*, only smaller, and many Times are cast by hand, being made of Iron, Brass, Glass, or Earth.



A TABLE

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A TABLE of the Dimensions of the common *English* Ordnance.

Names of Pieces.	Diameter Bore.	Len. Cha.	Powd. & Requi.	Bullets Diameter.	Greater Randoms.	Comp. Force.	Comp. Time.
	Inch.	Feet	Pound.	Inch	Mi'es.		
A Rabbinet.	1.75	3	0.333	1.4	3.760	38	20589
A Falconet	2.	4	0.580	2.1	4.198	61	14898
A Falcon.	2.75	6	1.646	2.6	4.797	166	5936
A Minion.	3.	8	2.612	2.8	5.864	238	5097
A Saker.	3.5	9	4.000	3.3	5.654	371	3152
A Demi-Culverin	4.5	10	7.347	4.3	4.886	732	1379
A Culverin.	5.	11	9.977	4.7	4.837	1000	1000
A Demi.Cannon.	6.	11	14.367	5.8	4.031	1577	528
A whole Cannon.	7.	12	21.333	6.7	3.709	2422	322
A Cannon Royal.	8.	12	27.864	7.5	3.298	3382	202

In the preceding Table is set down the Names, Diameters of Bores, and Lengths of the Chases, of several Pieces of our *English* Ordnance, with their Requisites of Powder and Ball, greatest Randoms, and comparative Forces and Times. Its use is thus : The first Column next the Left-hand gives the Name of each Piece, the second Column gives the Diameters of their Bores in Inches and decimal Parts of an Inch, the third shews the Length of their Chases in Feet and decimal Parts of a Foot, the fourth the Requisite of Powder to each Piece in Pounds and decimal Parts of a Pound, the fifth has the Diameter of each Ball or Bullet in

Inches and Tenths, supposing four Pounds to be the Requisite of the Saker; the sixth contains their greatest * Randoms in Miles and decimal Parts of a Mile, supposing the greatest Random of the Saker to be 5.654 Miles, as found by Experiment; the seventh contains their comparative Forces one to another, when taken in like Places; in the eighth is the comparative Times of the Ranges of their Shot on equal Elevations, that is thus: Suppose a Falconet and Demi-Culverin be elevated to the same Degree, then the Force of the Falconet to that of the Demi-Culverin, is as 61 to 733, and their Times of Continuance in the Air, is as 14898 to 1379.

To know the different Fortifications of a Piece of Ordnance.

In fortifying any Piece of Ordnance, there are three Degrees observed, viz. *Bastard*, *Legitimate*, and *Double Fortified*.

Bastard are such as are the least fortified of all.

Legitimate are such as are ordinarily fortified, that is, more than the Bastard.

Double Fortified Pieces are such as are fortified above either of the former, and are termed extraordinary.

The Fortification of any Piece of Ordnance, is accounted by the Proportion of the Thickness of the Metal at the Touch-hole, Trunnions and the Muzzel, compared to the Diameter of the Bore.

The Bastard Cannon have $\frac{1}{4}\frac{2}{6}$ at their Touch-hole, $\frac{7}{8}\frac{0}{6}$ at their Trunnions, and $\frac{5}{6}$ at their Muzzel of the Diameter of the Bore, in Thickness of Metal.

* *Random signifies the Angle of Elevation, and Range the Distance the Shot is flung.*

Legitimate

Legitimate Pieces, or ordinary fortified Cannons, have $\frac{7}{8}$ at the Touch-hole, $\frac{5}{8}$ at the Trunnions, and $\frac{3}{4}$ at the Muzzle.

The *double fortified Cannon* have one Diameter of the Bore in Thickness of Metal at the Touch-hole, $\frac{11}{16}$ at the Trunnions, and $\frac{7}{8}$ at their Muzzle. Now all double fortified Culverins, &c. are $1 \frac{1}{8}$ at the Touch-hole, $\frac{5}{8}$ at the Trunnions, and $\frac{9}{8}$ at the Muzzle; and the ordinary fortified Culverins are fortified every Way as double fortified Cannons, and lessened Culverins as ordinary Cannons, in all respects.

To know how much Powder is fit for Proof, and for Service for any Piece of Ordnance.

For *Cannons* take $\frac{4}{5}$ of the Weight of their Iron Bullet, of good Corn Powder for Proof, and for Service $\frac{1}{2}$ the Weight of the Iron Bullet is sufficient, especially for Iron Ordnance, which will not endure so much Powder as Brass ones will receive for $\frac{1}{4}$ in Weight; for Culverins allow the whole Weight of the Shot for Proof, and $\frac{2}{3}$ for Service. For Sakers and Falcons take $\frac{4}{5}$ of the Weight of the Shot; and for lesser Pieces, the whole Weight may be used in Service, until they grow hot; but then there must be some Abatement made at Discretion, and take $\frac{1}{3}$ of the Weight of their Bullets for Proof.

To know what Bullet is fit to be used in any Piece of Ordnance.

The Bullet must be somewhat less than the Bore of the Gun, that so it may have Vent in the

the Discharge, some Authors affirm $\frac{1}{4}$ of an Inch less than the Bore will serve all Ordnance; but this Vent is too much for a *Falconet*, &c. and too little for a Cannon, therefore they are not to be approved; the best is Mr. *Phillips* his Proportion, which is to divide the Bore of the Gun into twenty equal Parts, and let the Diameter be $\frac{1}{20}$ thereof, according to which Proportion the preceding Table is calculated.

By knowing the Proportion of Metals one to another, and by knowing the Weight of any Ball, to know what any other shall weigh.

The common Proportion for Metals are these:

Lead is to Iron, as 2 to 3
 Lead is to Brass, as 24 to 19
 Lead is to Stone, as 4 to 1
 Iron is to Lead, as 3 to 2
 Iron is to Brass, as 16 to 18
 Iron is to Stone, as 3 to 8

The more exact Proportion betwixt Metals are thus known; admit a Cube or Ball of Gold weigh 100l. a Cube of any of those Metals ensuing of the same Bigness will bear such Proportion, to the said Cube of Gold, as the following Table expresses.

	lb.	pts.		lb.	pts.
Gold	100.	00	Iron	42.	10
Quicksilver	71.	43	Tin	38.	95
Lead	60.	53	Stone	15.	80
Silver	54.	39	Water	05.	68
Brass	47.	47			

By

By the help of this Table, having the Weight of a Ball of any Metal, with its Diameter proposed, it is easy to find the Weight of any other Ball, either of the same or different Metal, whose Diameter is given, and *Contra*.

In order to this, we shall take Dr. Wybard's Opinion in his *Tactometria*, that a Bullet of cast Iron, whose Diameter is four Inches, weighs nine lb. *Averdupoize* Weight. This being granted, suppose the Diameter of an Iron Ball be six Inches, what must it weigh?

For determining this Question, and others of the like Nature, this is the Rule: As the Cube of the first Diameter to the Cube of the second, so is the Weight of the first to the Weight of the second.

Now the Cube of 4 is 64, and the Cube of 6 is 216, therefore I say,

As 64 to 216, so is 9 to $30\frac{3}{4}$, or 30 l, 6 oz.

If the Weight of a Brass Bullet had been required whose Diameter is six Inches, first calculate its Weight as if it were Iron, and then by the preceding Table say, as 42 lb. 10 oz. to 47 lb. 37 pts. so is 30 lb. 6 oz. to 34 lb. 2 oz. near, which is the true Weight of it, were the Ball Brass, and had six Inches Diameter.

How to tertiate, quadrate, and dispart, a Piece of Ordnance.

First, To *tertiate* a Piece, is to find whether it hath its due Thickness at the Trunnions, Touch-hole and Neck, if the Trunnions and the Neck are in their due Order, and the Chase streight.

Q 4

Secondly,

Secondly, To *quadrate* a Piece mounted, is to see whether it be directly placed, and equally poized in the Carriage, which is known by finding in the Convex Superficies of the Base and Muzzel Ring, the Point which is perpendicular over the Soul of the Piece, which may be found by the Gunner's Instrument, called a Level, an Instrument whose use is so vulgarly known that it needeth not my Explanation.

Thirdly, To *dispart* a Piece, is to fix or elevate on the Convex Point of the Muzzel Ring, a Mark as far distant from the Cylinder, or Soul of the Piece, as is the Point of the Base Ring to the End, that the visual Ray, which passeth by these Marks, may be parallel to the Chase, Soul, or Cylinder of the Piece; now the *Dispart*, i. e. the Difference of the Semi-Diameters of the Cornishes may be taken by a Pair of Calliper Compasses; which found, place on the Top of the Cornish Ring, near the Muzzel, over the Middle of the inferior Cylinder.

Some general Rules to be observed in Shooting in long Guns and Mortars.

First, That a Shot at right Angles strikes more violent and furiously than at oblique Angles, therefore Gunners use, when they are to batter down a Tower, Wall or Earth-work, to shoot point blank at the Object, *Tire by Tire*, by discharging all the Pieces in Battery against the self-same Object in the same Instant; holding it for a Maxim, That ten Cannons discharged together do far more Execution than discharged one after another; now at oblique Angles, they shoot either Cross-ways or by rebounding.

Secondly,

Secondly, That the speediest Way to make a Breach in the Wall, &c. is by shooting at the Object from two Batteries, which ruins far more speedily than by striking the Object with one Battery at right Angles, although that one Battery hath as many Cannon as the other two hath.

Thirdly, That if you were to batter a Flank, covered with an Orillon (which because you cannot possibly batter it right forward) you must therefore of necessity batter it obliquely, by Way of rebounding, thus : Choose a fit Place in the Curtain to be your Object, on which you may play with your Battery obliquely, so that by a Rebound the Shot may leap into the Flanks ; holding it for a Maxim, in this Operation, That the Angles of Incidence and Reflection are equal.

Fourthly, In Mortars, before you make a Shot at any Place, you find the Distance thereof from your Mortar.

Fifthly, That the Bombs, or other Bodies that are to be shot, be of equal Weight ; otherwise the Shots will vary.

Sixthly, That the Carriage in Breadth be always on a Level, and without any Descent, that so it may not leap in discharging.

Seventhly, That the Powder with which the Mortar is loaded, be always of the same Force and Weight,

Eighthly, That the Charge of the Mortar, as well in Powder as in Wadding, be always rammed in with Blows equally heavy, and of equal Number.

Ninthly, That the Wads be always either of Wood or Tompions, or else of Okam, for the strongest drives it farthest.

Tenthly,

Tenibly, That the Fuses be newly made, in those Days that they are to be used, and that they be made of a Composition proportionable to the Range that the shoot shall make in the Air, so that the Bomb may break in the very Moment of its fall, which Composition must be such, that though it fall in the Water, yet not to extinguish, but the Bomb there to break. Now before we proceed any farther, I think it necessary, to shew how to compose your Ingredients for your Fuse.

To make Fuses for Bombs, &c.

The Composition for Bombs must be of a slow Motion, that so Time enough may be given to throw either Bombs, Granadoes, Fire-Balls, Thundering-Barrels, &c. They are compounded of these Ingredients thus: Take a Pound of Gunpowder, $\frac{1}{8}$ of Sulphur, $\frac{1}{8}$ of Salt-petre, well beaten, dry, and sifted separately, then mix it, and make up your Fuse thereof; or take Powder of Benjamin, and Small-Coals, all well beaten, and mixed together with some Oil of Peter, and so fill your Fuse therewith.



Of Shooting in general.

AS to the *several Shootings in Artillery*, Authors have differed much in their Opinions ; but now they all unanimously agree, That a Ball being shot forth describes in the Air a *Parabolick Line*, as has been proved by *Gallilæus*, *Torricellius*, and of late by the ingenious Capt. *Halley*, in a Discourse of Gravity, published in *Philos. Transac. Numb. 179*. In which Discourse he mathematically demonstrates, that the Motion of all Projects is in the *Curve of Parabola*. From the Properties of which *Curve*, these useful Things in Gunnery have been deduced.

First, That the Length of the horizontal Ranges are one to another, *as the Sines of the double Angles of Elevation*.

Secondly, That the *Altitudes* of Shots are one to another, *as the versed Sines of the double Angles of Elevation*.

Thirdly, The Times of Continuance of a Shot in the Air, at different Elevations, are one to another, *as the Sines of the Angles of Elevation*.

From these three Propositions all that is necessary, in the Practice of Gunnery, may be known.

As *First*, Suppose I make a Shot upon a given Elevation, and then measure the Length of the Range Shot ; you may from that Distance by the preceding Proposition tell the Length of the Ranges Shot, upon any other Elevation, using the same Force or Charge of Powder.

For

For Example: Suppose a Shot with a Mortar be made upon fifteen Degrees Elevation, and measuring the Range find it 300 Yards, it is required to know the utmost Range, or how far it will shoot at forty-five Degrees.

<i>Say,</i>	
As Sine 30 Degrees	9. 698971
To Sine 90 Degrees	10. 000000
So is 300 Yards	12. 477121
To 600 Yards	2. 778151

So that the greatest horizontal Range (of a Mortar that throws a Bomb upon fifteen Degrees Elevation 300 Yards) is 600 Yards.

After the same Manner are the Range upon all Elevations found. As suppose you would find the horizontal Range upon thirty-five Degrees Elevation.

<i>Say,</i>	
As Sine 30	9. 698970
To Sine 70	9. 973986
So is 300 Yards	2. 477121
	12. 451107
To 565 Yards	2. 752137

Again, Suppose I had a Mind to find what Elevation of my Piece is requisite to hit a Mark at 400 Yards Distance from me.

Say,

Say,	
As 300 Yards	2. 477121
To Sine 30 Degrees	9. 698970
So is 400 Yards	2. 602060
	12. 301030
To Sine 41, 48	9. 823909

The half of which is 20, 54, the 7 of Elevation for the Piece to throw a Bomb 400 Yards.

And thus, this one Property is sufficient without a Table of Ranges, the Table of Ranges being made by this Proportion.

And here note, That you may work these Proportions by the Lines of *artificial Numbers* and *Sines*, which are put upon the common *Gunters Scales*.

From this Proposition it follows, that the greatest horizontal Range of any Project is at forty-five Degrees, and that the horizontal Ranges above and below forty-five Degrees are equal.

Secondly, The *Altitudes* of Shots are one to another as the versed Sines of the double Angles of Elevation.

And here note, That the greatest Height that a Ball will ascend to when shot perpendicular upright, is $\frac{1}{2}$ the greatest Range; and therefore knowing the greatest Range of your Piece by the first Proposition. which supposing 600 Yards, and you would know how high the Ball would fly when the Piece is set to forty Degrees of Elevation.

Say,

Say,

As the versed Sine of 180 (*viz.* twice the *Rad.*) is to the versed Sine of eighty (*viz.* twice forty Degrees) so is $\frac{1}{2}$ the greatest Range to the Altitude required.

So that multiplying the versed Sine of eighty Degrees, which is 8263, by 300 Yards, half the greatest Range, and dividing the Product by 20000 the versed Sine of 180, the Quot. is near 124 Yards, the perpendicular Height.

See the following Operation.

$$\begin{array}{r} 8263 \\ 300 \\ \hline 2(0000)247|8900|124 \text{ prope.} \end{array}$$

And on the contrary, if the greatest horizontal Range was given, and the perpendicular Height of any Shot known, then to find the Angle of Elevation.

Say,

As 300 Yards half the greatest horizontal Range, to the versed Sine of 180 Degrees, *viz.* 20000, so is the given perpendicular Height of a Shot, suppose 124 Yards to 8263, near the versed Sine of eighty Degrees, half of which is forty Degrees, the Angle the Piece must be set to.

Thirdly, The *Times* of the Continuance of a Shot in the Air at different Elevation, are one to another as the Sines of the Angles of Elevation.

Now

Now suppose I had made a Shot upon forty-five Degrees of Elevation, and by a Watch which hath a Hand to shew Seconds, I find that the Shot continues in the Air twelve Seconds, it is required to know how long it will continue in the Air when shot at seventy-five Degrees of Elevation.

Say,

As the Sine of 45 Degrees

9. 849485

Is to 12 Seconds

1. 079181

So is the Sine of 75 Degrees

9. 984944

11. 064125

To 16 Seconds

1. 214640

By this Rule *Fuses* are adjusted, as to their Time of Burning, that they might break just at their fall.

Again, if at fifty-four Degrees of Elevation a Shot continues in the Air fourteen Seconds, how many Degrees was the Piece elevated to; when the Shot continued sixteen Seconds in the Air?

I might have proceeded further, in shewing how from several Data's to find the *Requisite* of *Powder*, Length of the *Chase*, *Diameter* of the Ball, &c. But these not being so absolutely necessary (especially to be acquired after this Manner) I have omitted them; and shall conclude this Tract with a very useful and easy Table, by which may be found the horizontal Random of any Shot from some given Elevation, as also the Elevation being given, to throw a Shot to any Place at demand. And that without the Help of the *Logarithmetical* Tables.

A TABLE

A TABLE of the horizontal Distances of Projections.

Deg.	Elev.	0	6	12	18	24	30	Mi.
0	0	0	7	14	21	28	35	89
1	70	77	84	91	98	105	112	88
2	140	146	153	160	167	174	181	87
3	209	216	223	230	237	244	251	86
4	278	285	292	299	306	313	320	85
5	347	354	361	368	375	382	389	84
6	416	423	429	436	443	450	457	83
7	484	491	497	504	511	518	525	82
8	551	558	565	571	578	585	592	81
9	618	625	631	638	645	651	658	80
10	684	691	697	704	710	717	724	79
11	749	756	762	769	775	781	788	78
12	813	820	826	833	839	845	852	77
13	877	883	889	896	902	908	915	76
14	939	945	951	957	964	970	977	75
15	1000	1006	1012	1018	1024	1030	1037	74
16	1060	1066	1072	1078	1083	1089	1096	73
17	1118	1124	1130	1136	1141	1147	1154	72
18	1171	1177	1183	1189	1195	1201	1208	71
19	1231	1237	1242	1248	1253	1259	1266	70
Mi.	60	54	48	42	36	30	24	Deg. Elev.

The Table continued.

Deg.	0	6	12	18	24	30	Mi.
20	1286	1291	1296	1302	1307	1312	69
21	1338	1343	1349	1354	1359	1364	68
22	1389	1394	1399	1404	1409	1414	67
23	1439	1444	1448	1453	1458	1463	66
24	1486	1491	1496	1500	1505	1509	65
25	1532	1537	1541	1545	1550	1554	64
26	1576	1580	1585	1589	1593	1597	63
27	1618	1622	1626	1630	1634	1638	62
28	1658	1662	1666	1670	1674	1677	61
29	1696	1700	1703	1707	1711	1714	60
30	1732	1736	1739	1742	1746	1749	59
31	1766	1769	1772	1776	1779	1782	58
32	1798	1801	1804	1807	1810	1813	57
33	1827	1830	1833	1836	1838	1841	56
34	1854	1857	1860	1862	1865	1867	55
35	1879	1882	1884	1886	1889	1891	54
36	1902	1904	1906	1908	1911	1913	53
37	1923	1924	1926	1928	1930	1932	52
38	1941	1942	1944	1946	1947	1949	51
39	1956	1958	1959	1961	1962	1963	50
40	1970	1971	1972	1973	1974	1975	49
41	1981	1981	1982	1983	1984	1985	48
42	1989	1990	1990	1991	1992	1992	47
43	1995	1996	1996	1996	1997	1997	46
44	1999	1999	1999	1999	2000	2000	45
Mi.	60	54	48	42	36	30	Deg. Elev.

The Table continued.

<i>Deg.</i> <i>Elev.</i>	36	42	48	54	60	<i>Min.</i>
0	42	49	56	63	70	89
1	112	119	126	133	140	88
2	181	188	195	202	209	87
3	251	258	265	271	278	86
4	320	327	334	340	347	85
5	388	395	402	409	416	84
6	457	463	470	477	484	83
7	524	531	538	545	551	82
8	591	598	605	611	618	81
9	658	664	671	677	684	80
10	723	730	736	743	749	79
11	788	794	801	807	813	78
12	852	858	864	870	877	77
13	914	920	927	933	939	76
14	976	982	988	994	1000	75
15	1036	1042	1048	1054	1060	74
16	1095	1101	1107	1113	1118	73
17	1153	1159	1164	1170	1176	72
18	1209	1215	1220	1226	1231	71
19	1264	1269	1275	1280	1286	70
20	1317	1323	1328	1333	1338	69
21	1369	1374	1379	1384	1389	68
22	1419	1424	1429	1434	1439	67
23	1467	1472	1477	1482	1486	66
24	1514	1519	1523	1528	1532	65
<i>Mi.</i>	24	18	12	6	0	<i>Deg.</i> <i>Elev.</i>

The Table continued.

Deg.						Min.
Elev.	36	42	48	54	60	
25	1559	1563	1567	1572	1576	64
26	1601	1606	1610	1614	1618	63
27	1642	1646	1650	1654	1658	62
28	1681	1685	1689	1692	1696	61
29	1718	1721	1725	1729	1732	60
30	1753	1756	1759	1763	1766	59
31	1785	1788	1791	1795	1798	58
32	1816	1818	1821	1824	1827	57
33	1844	1846	1849	1852	1854	56
34	1870	1872	1875	1877	1879	55
35	1893	1896	1898	1900	1902	54
36	1915	1917	1919	1921	1923	53
37	1934	1935	1937	1939	1941	52
38	1950	1952	1953	1955	1956	51
39	1965	1966	1967	1968	1970	50
40	1976	1978	1979	1980	1981	49
41	1986	1987	1988	1988	1989	48
42	1993	1994	1994	1995	1995	47
43	1998	1998	1998	1999	1999	46
44	2000	2000	2000	2000	2000	45
Min.	24	18	21	6	0	Deg. Elev.

The Use of the preceding Table is thus.

The Left-hand Page is the Degree of Elevation, and the Top are the Minutes to the 10 of a Degree, that is, to 6, 12, and 18.

Suppose now a Piece elevated to 13 Degrees 18 Minutes, lays the Ball at 1837 Paces Distance, what is his greatest Random?

Seek in the Table for 13 Degrees, and under 18 Minutes on the Top is 896, the Tabular Distance.

Therefore say, as 896 to 2000, so is 1837 to 4100 Pieces, the greatest Random of the said Piece.

The same would follow, if the Elevation had been 76 Degrees 42 Minutes, that being as much above 45 Degrees, as 13 Degrees 18 Minutes is under, and may easily be found by looking on the Right-hand Side in the Bottom of the Table.

Secondly, The greatest horizontal Projections of a Piece being 41000.4 Paces, how must I elevate my Piece to throw a Ball 1737 Paces?

Say, as 41000.4 to 2000, so is 1737 to 896 near. This Number 896, or nearest, being found out in the preceding Table, you have in the Left-hand Column 13 Degrees, and in the Head of the Table over the Number you have 18 Minutes, which is the true Elevation of the Chase of the Piece to lay a Ball at the afore-mentioned horizontal Distance of 1837 Paces; or if you look in the Right-hand Column, and at the Bottom of the Table, you will find 76 Degrees 42 Minutes, the over Elevation to throw a Piece as aforesaid.

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I might have proceeded farther in giving more Examples, as also in relation to the Resistance of the Air (by which all Projects are diverted from describing in the Air a true Parabola) and consequently that the greatest Random is not made upon 45 Degrees of Elevation, but at some few Minutes under, and so will cause some small Difference in the horizontal Ranges.

But considering in ordinary and common Practice, (especially in Service) that with the common Instruments we can scarce come to the Certainty of a Degree or two, the preceding Table will be near enough, and serve very well for ordinary Practice, although the Allowance for the Air's Resistance be not considered therein.



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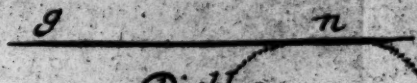
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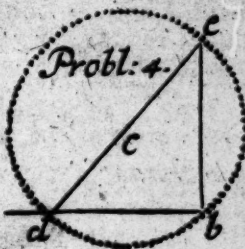
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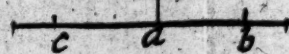
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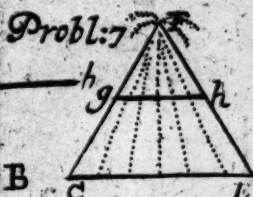
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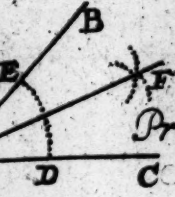
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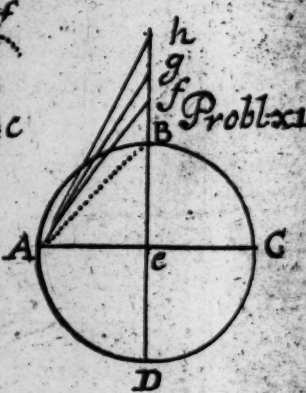
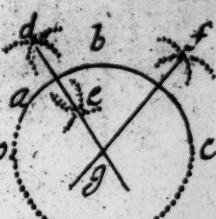
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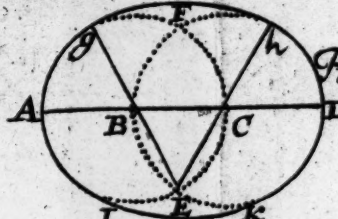
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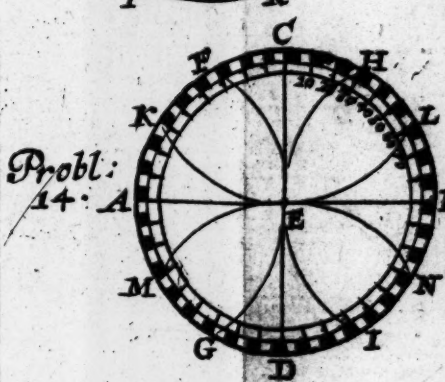
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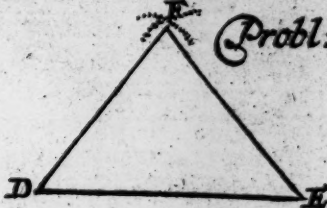


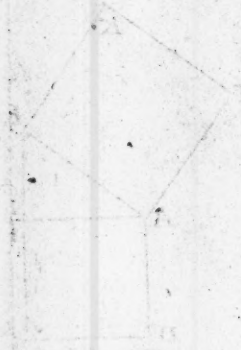
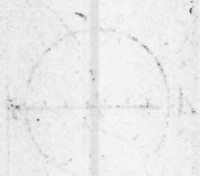
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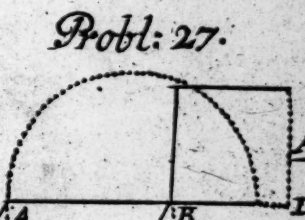
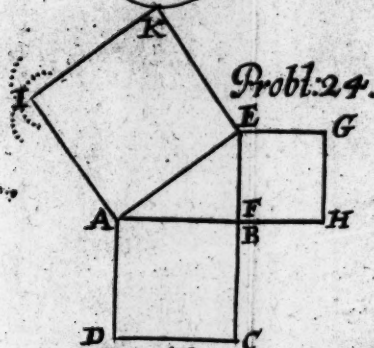
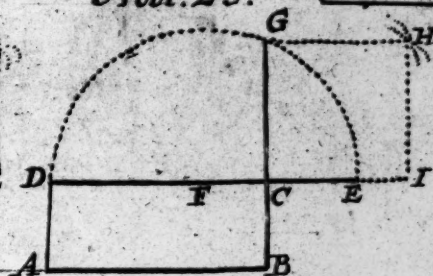
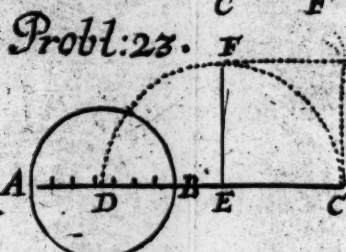
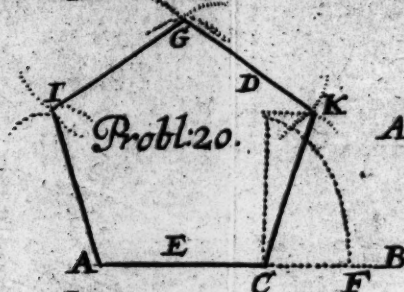
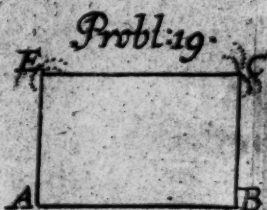
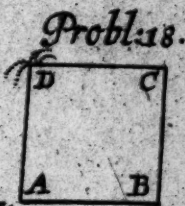
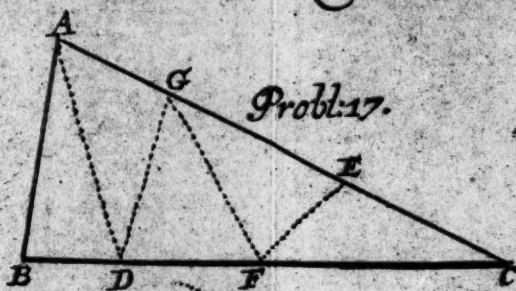




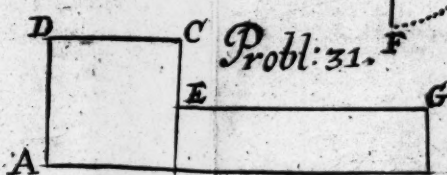
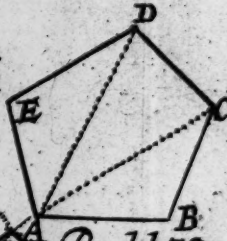
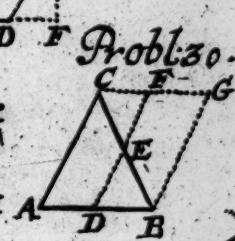
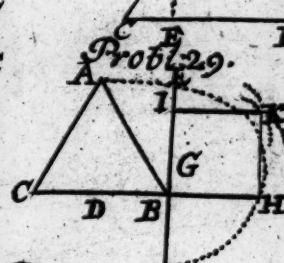
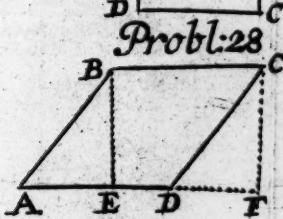
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A

For Chap. 2. Book 1. Geom. Pl. 2.



This is the right Angle triangle equal to the Circle in Prob. 21.





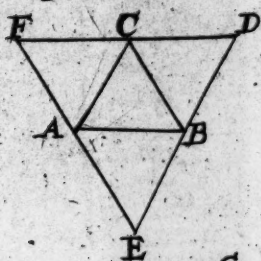
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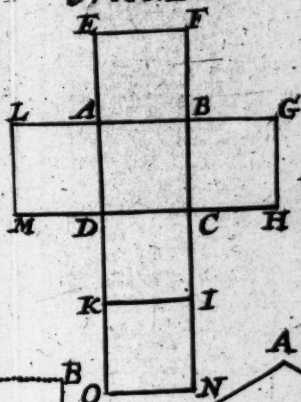
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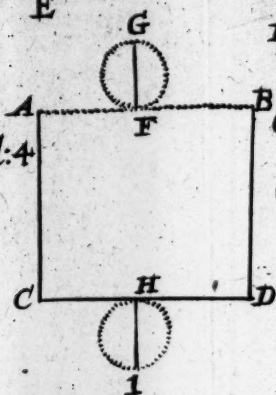
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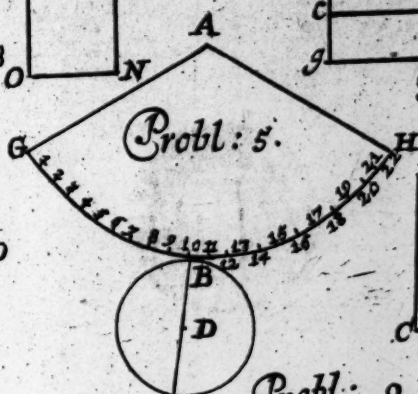
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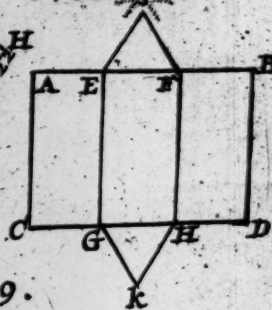
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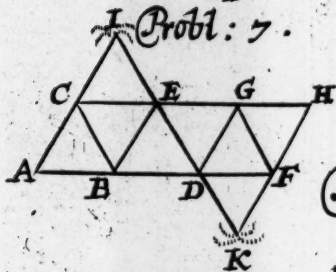
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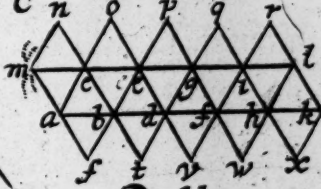
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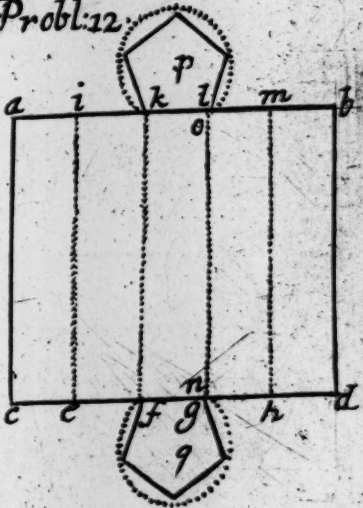
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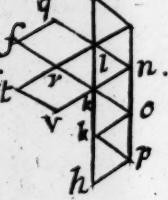
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Probl:XI.



For: Chap: 4 Books 1.

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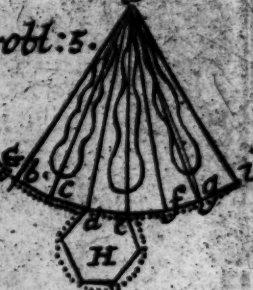
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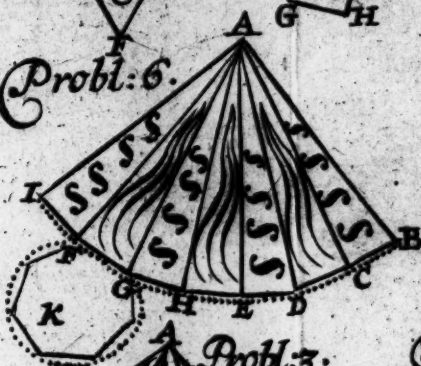
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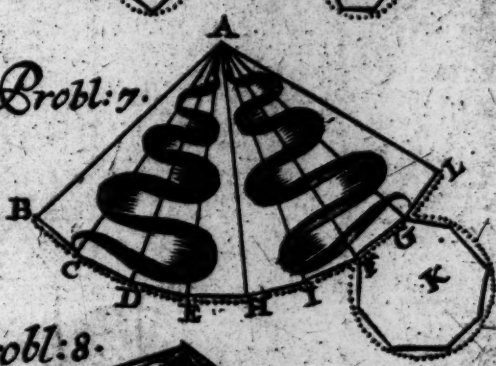
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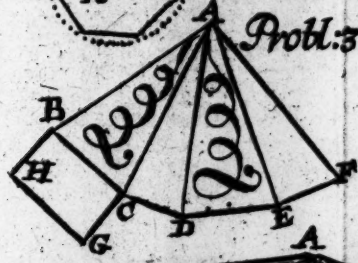
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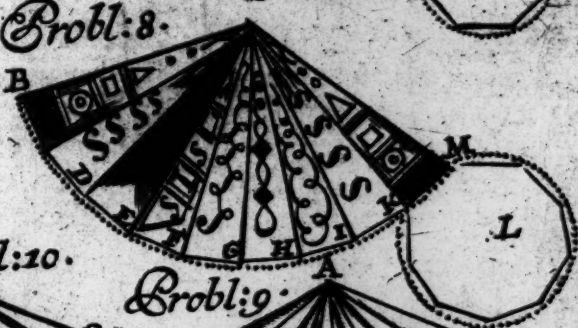
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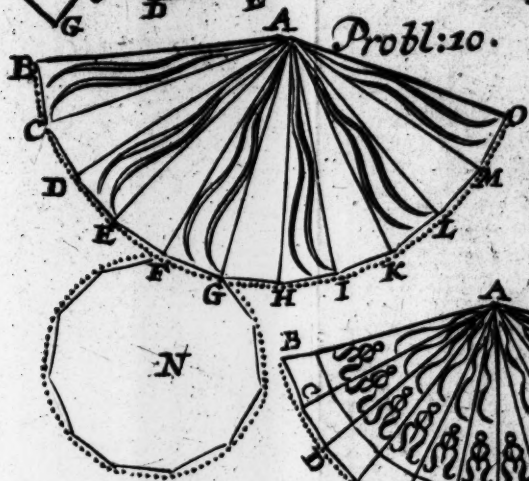
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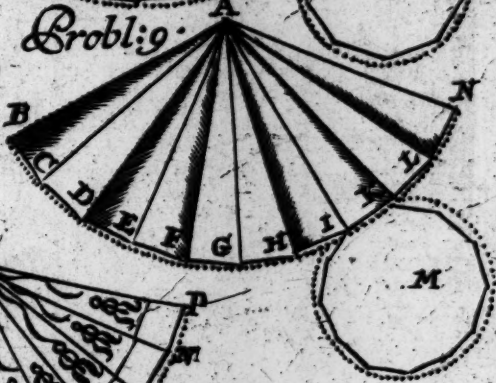
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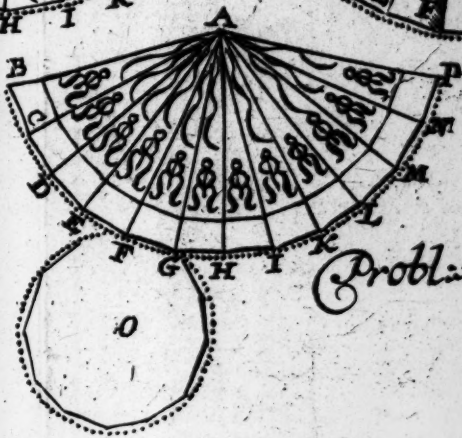
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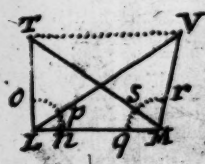
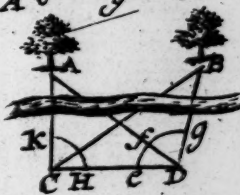
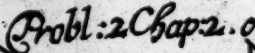
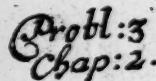
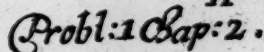
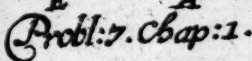
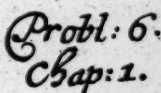
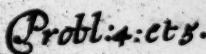
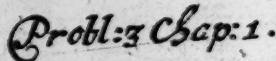
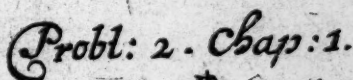
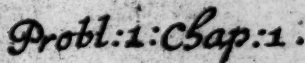




P

D

Geom. Plg.





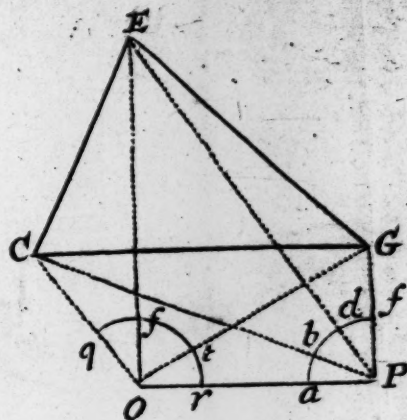
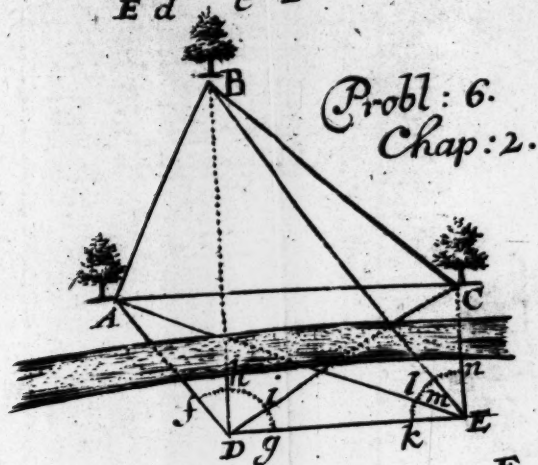
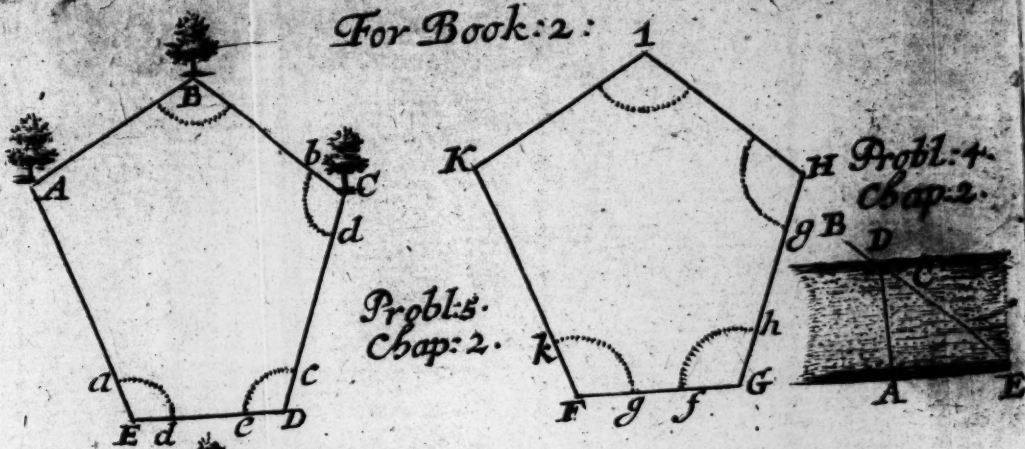
Pro
Ch



I

S

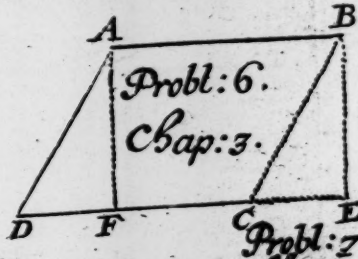
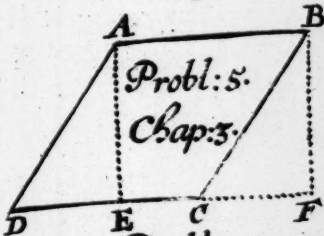
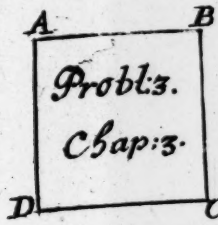
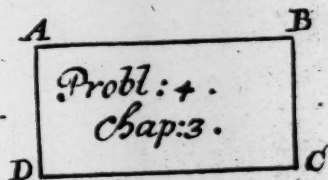
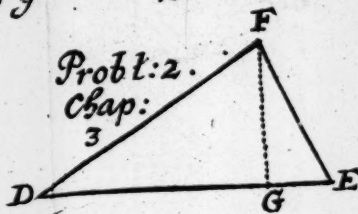
For Book: 2:



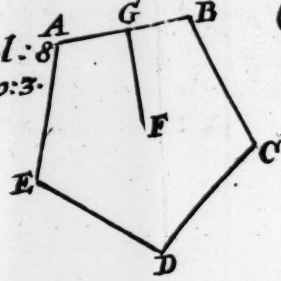
Probl: 11.
Chap: 3.



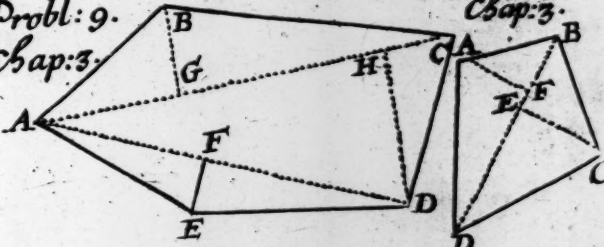
Probl: 2.
Chap: 3.



Probl: 8.
Chap: 3.



Probl: 9.
Chap: 3.

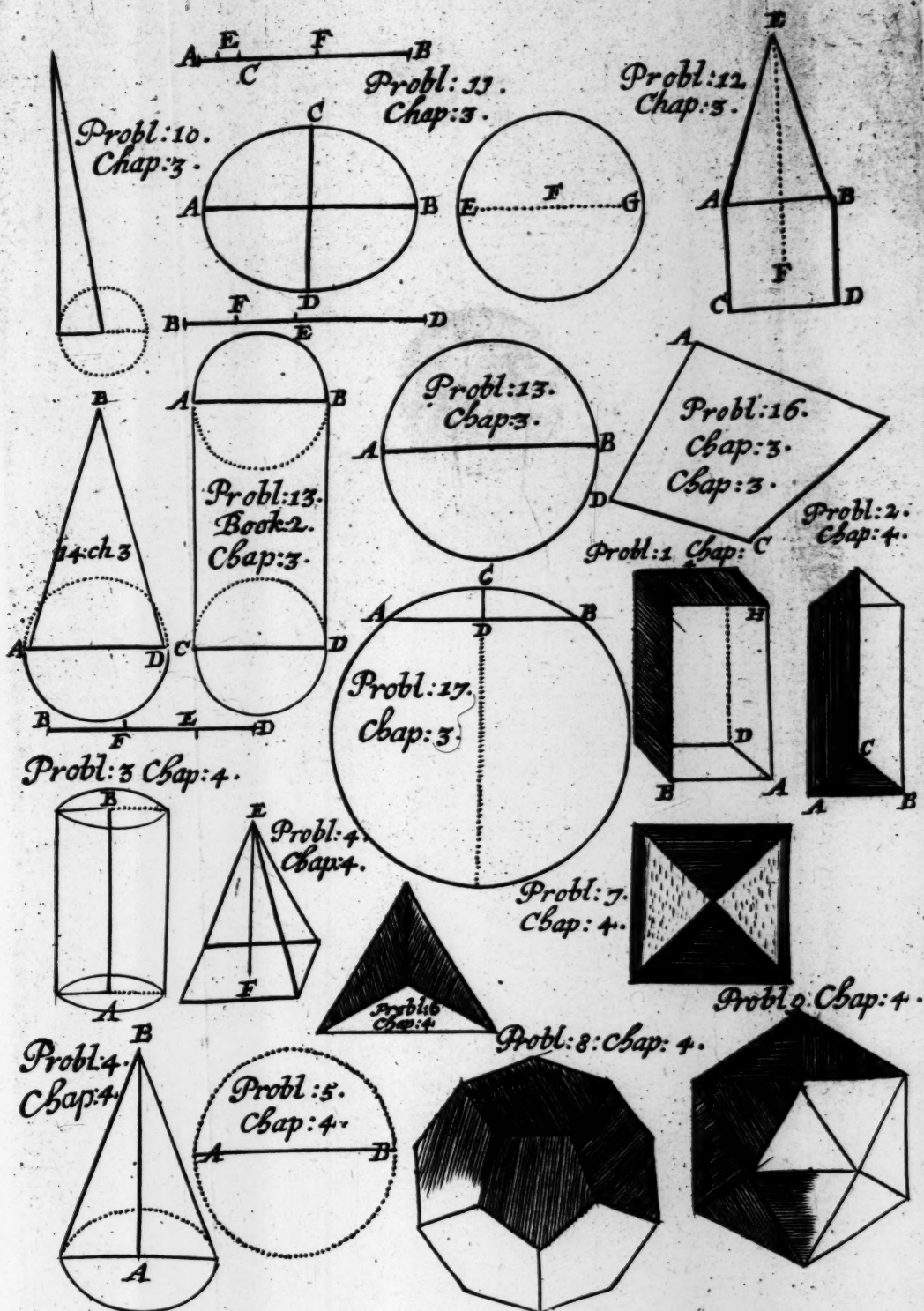


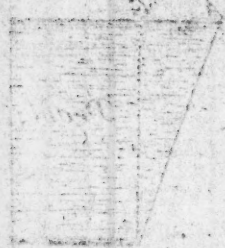
Probl: 7.
Chap: 3.



Geom: Pl: 6.







360°

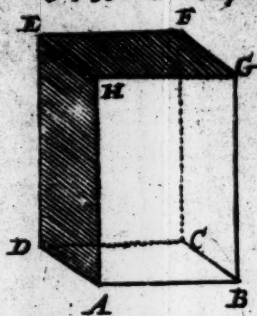




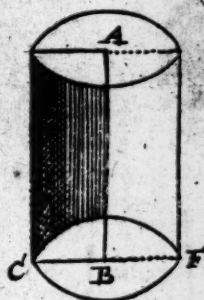
Probl: 2 Chap: 5



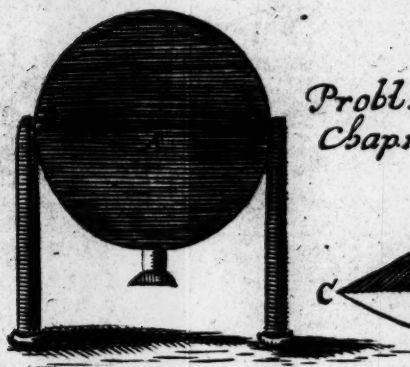
Probl: 8 & 9 Chap: 5



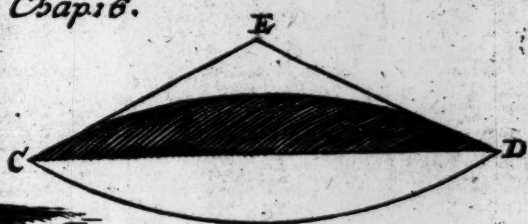
Probl: 1 Chap: 6



Probl: 2 & 4 Chap: 6



Probl: 10 Chap: 6



1870
1871
1872
1873
1874

A Figure shewing all the angles in a Square

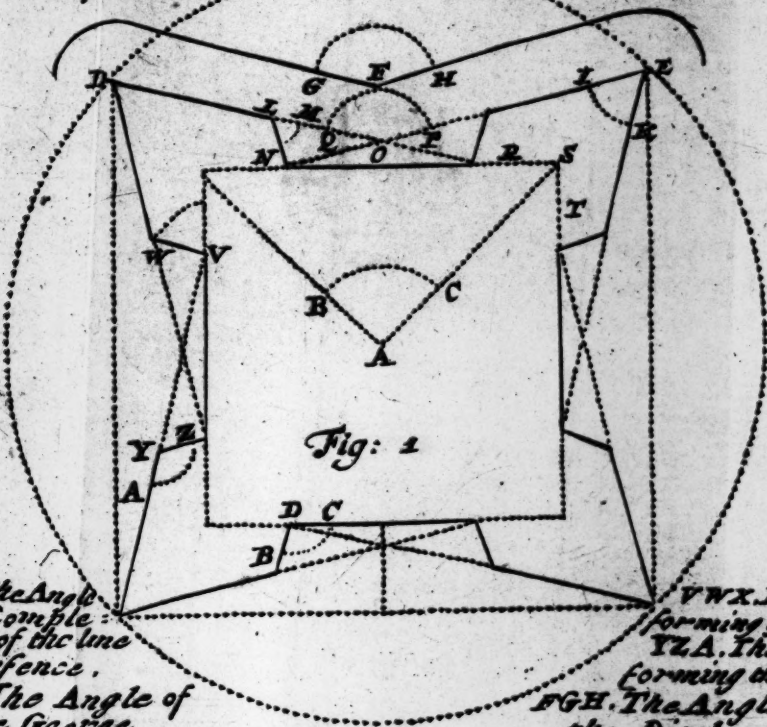
20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360

ABC. The Angle of the Center

EIK. The Angle of $\frac{1}{2}$ Bastion

DE. The Angle of the Circumference

LMN. The Flanking Angle



QPO. The Angle of the Complement of the line of defence.

RST. The Angle of the George

BCD. The Angle of $\frac{1}{2}$ Courtin

A

VWX. The angle forming $\frac{1}{2}$ flank

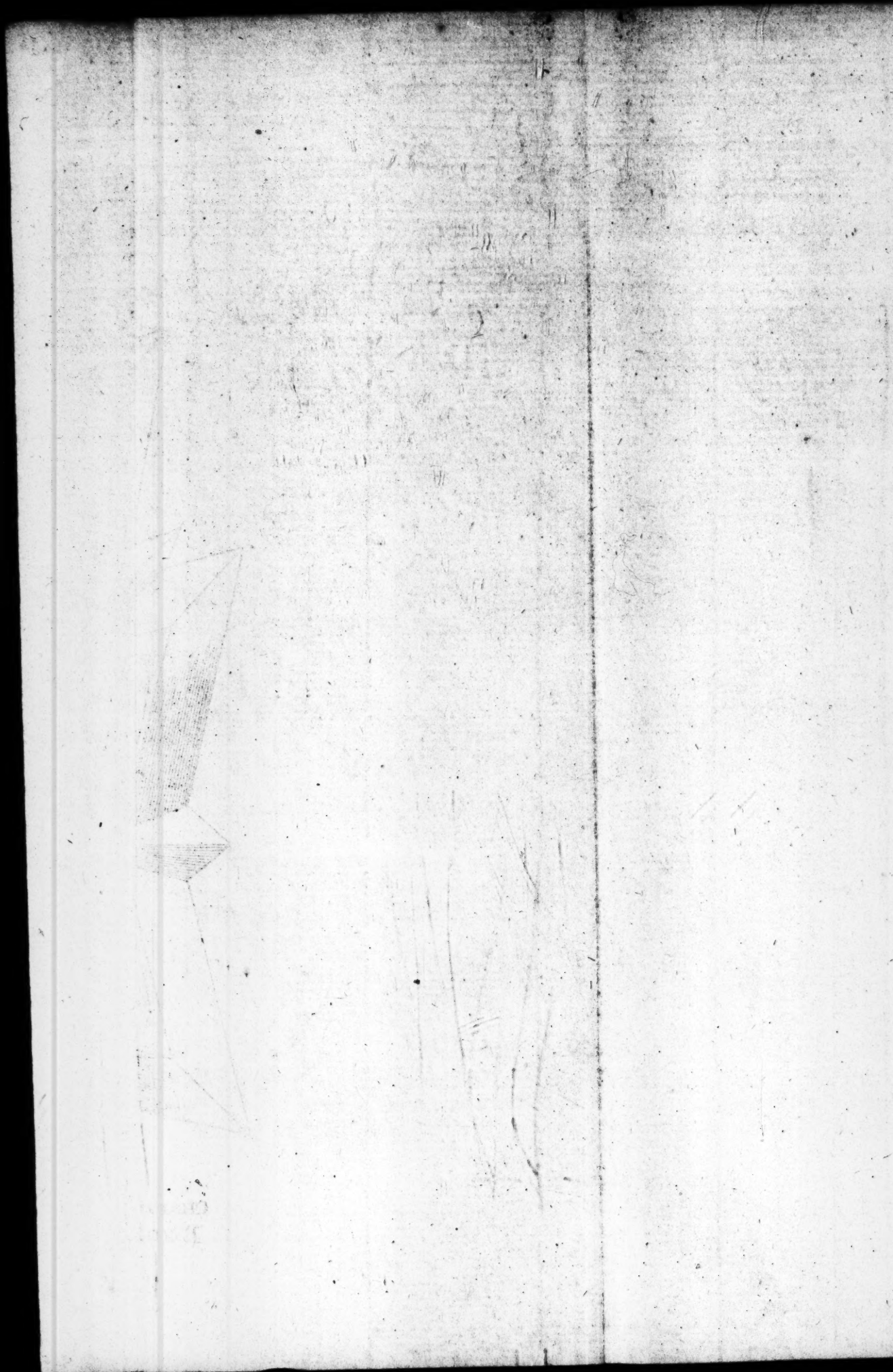
YZA. The Angle forming the Face

FGH. The Angle of the Ditch.

[illegible]

A Draught & Square of Vanbanc.





A Scale for this Draught

20 40 60 80 90 100 Fathoms.



CHAP. III. & IV. & V.
Book III.

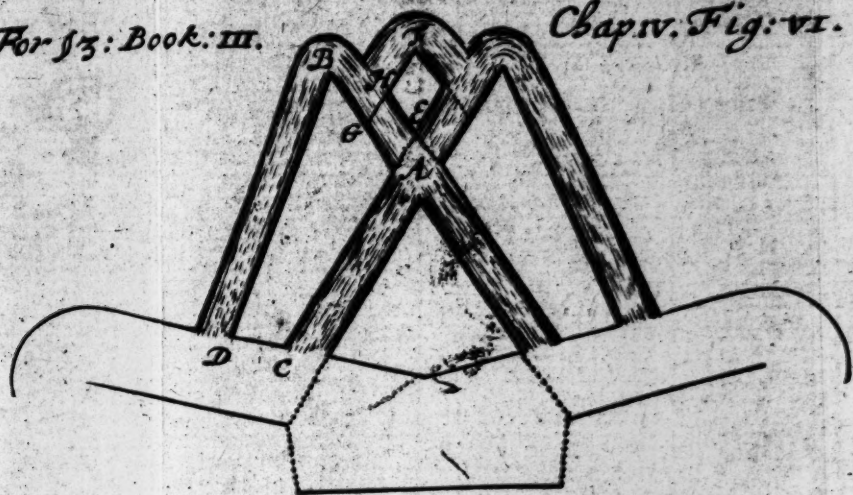
C



10 20 30 40 50 60 70 80 90 100 Fathoms

For 13: Book: III.

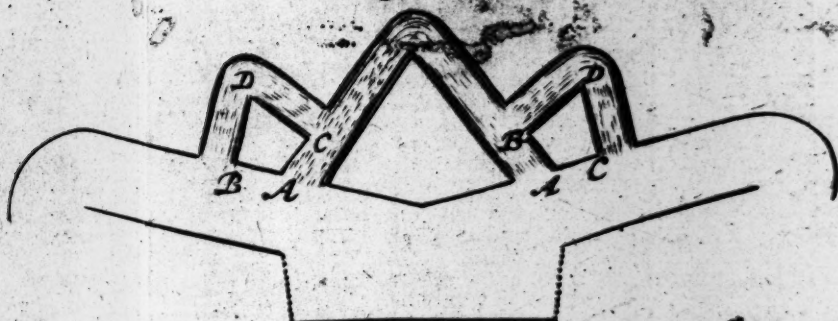
Chap: IV. Fig: VI.



For 12: Book III.

Chap: V.

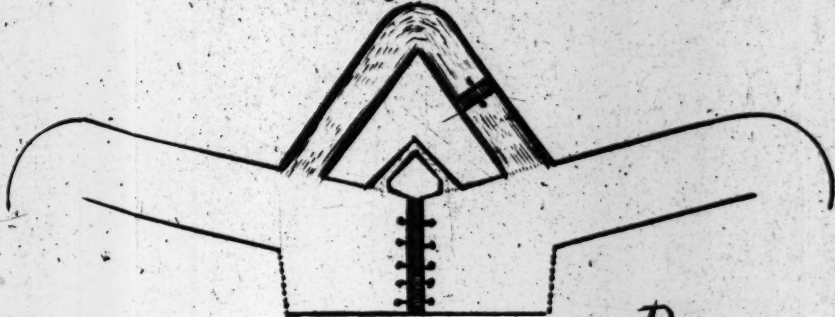
Fig: V.



For 14: Book III.

Chap: V.

Fig: VII.

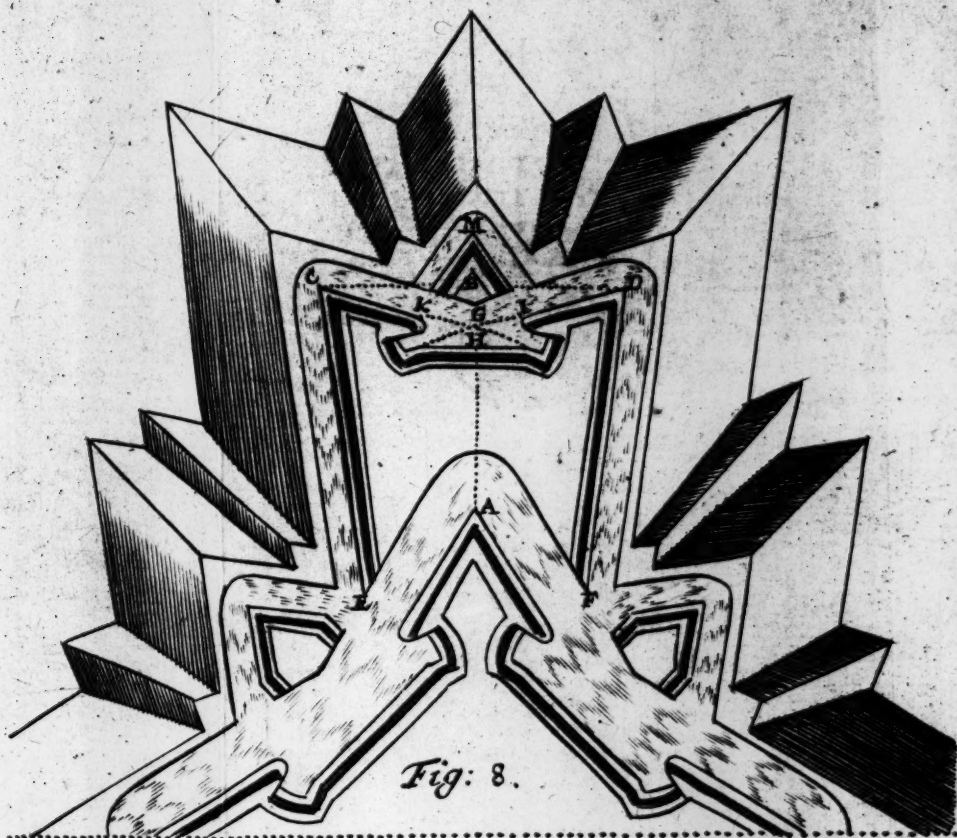




A Scale for this Plan

20 40 60 80 90 100 Fathoms.

CHAP. VII: *Book: III.*



*The Plan of a Horn work before
the Bastion of a Square.*

E

A. J. 1875

The
of
the

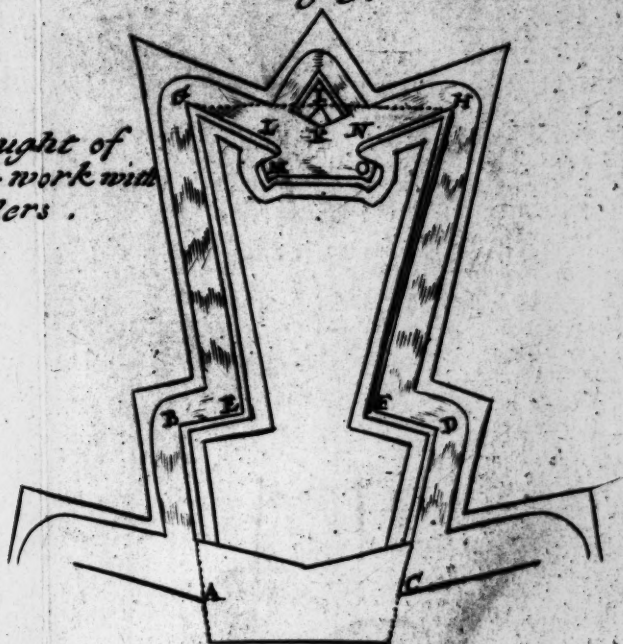
1875

A Scale of $\frac{1}{8}$ $\frac{32}{20}$ $\frac{24}{20}$ $\frac{56}{80}$ $\frac{70}{80}$ $\frac{96}{120}$ Fathoms.

CHAP. VIII. Book III.

Fig. 9.

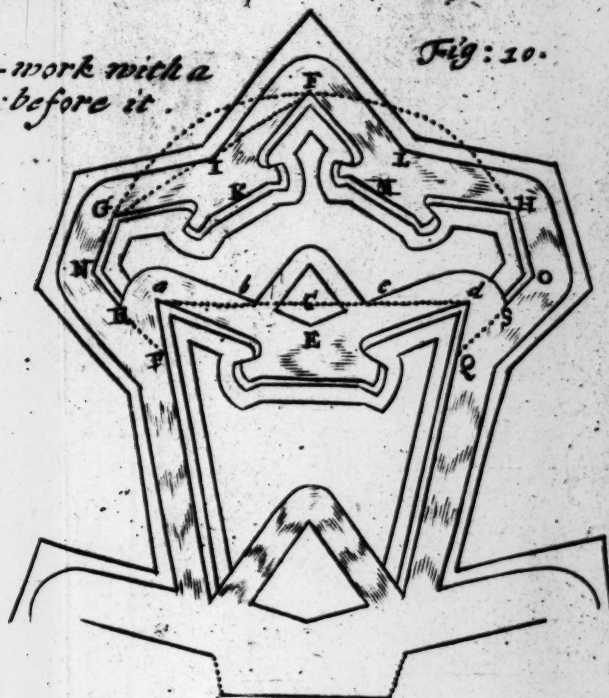
The Draught of
a Horn-work with
Shoulders.



CHAP. IX. Book III.

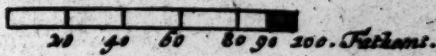
a Horn-work with a
Crown before it.

Fig: 10.



CH 2

Scale for this work



CHAP. X. Book III



*A draught of a
Square with a
Crown Work
before the
Courtin
Fig: 11.*

1875
1876

1877

1878

1879

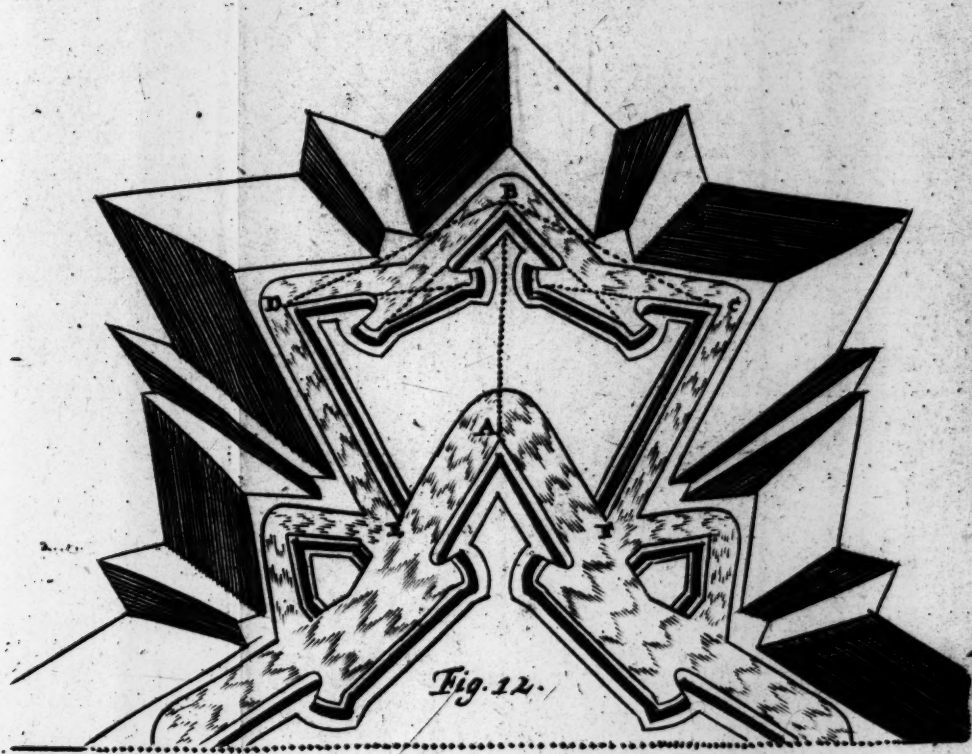
1880

A Scale of 100 Fathoms or 600 Foot
 Note a Fathom
 is 6 Foot.

The Scale of this Plan
 20 40 60 80 90 100 Fathoms

a Crown Work before the Bastion
 of a Square Vauban

CHAP: XI. Book III.



H



A Scale for this Plan

Fathoms.
20 40 60 80 100 120



1824

CHURCH

1824



A Scale for this Draught.  *Fathoms*

CHAP. XIII. BOOK III.

CHAP. XIV. BOOK III.

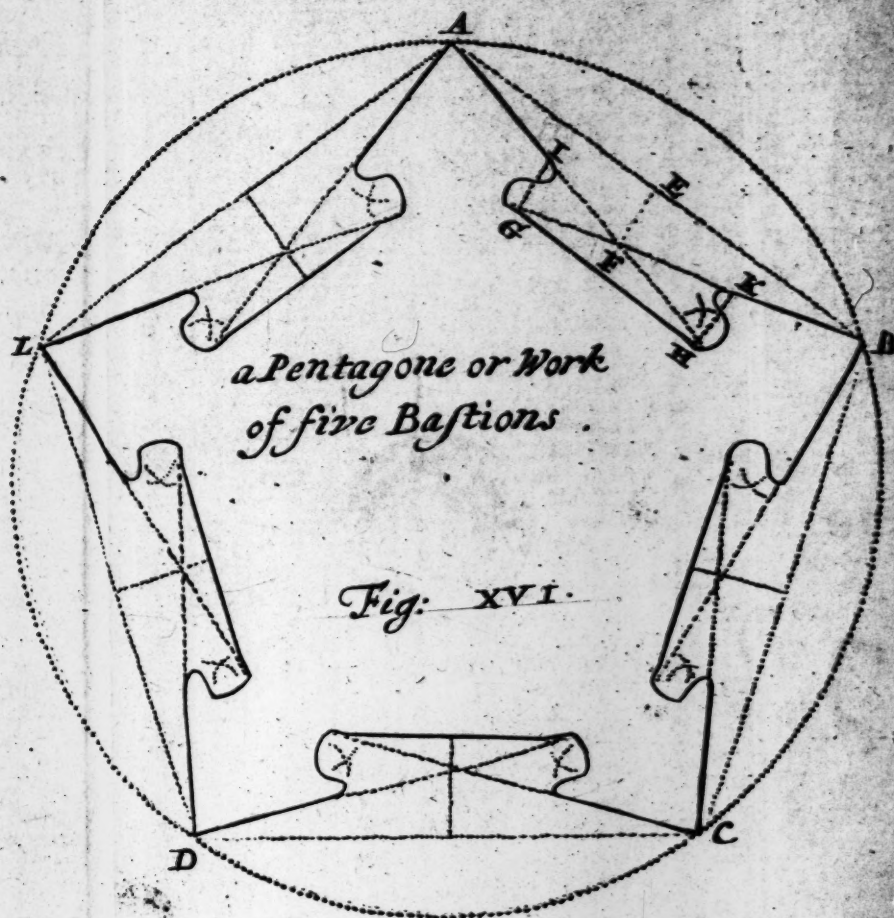
Fig: 15.



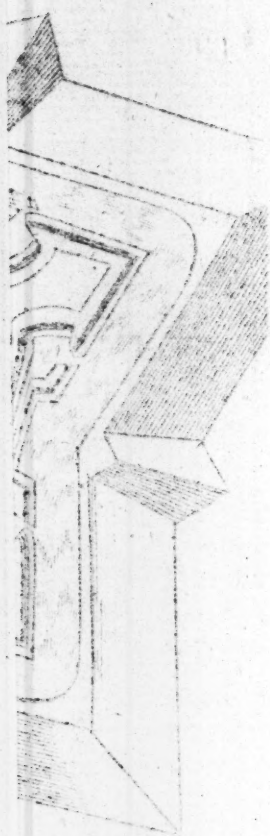
K

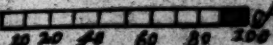


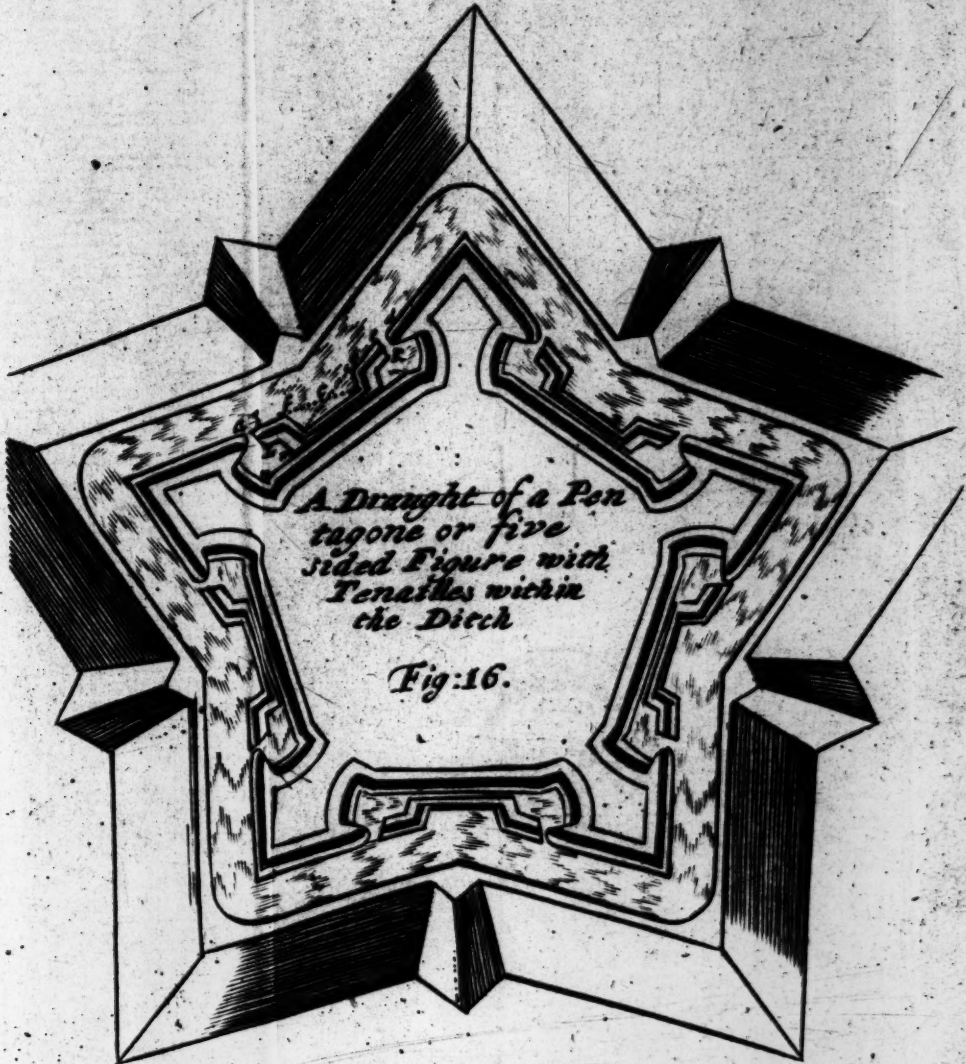
A Scale of  Fath.^s to this Draught.



Chap: XVI. Book. III.



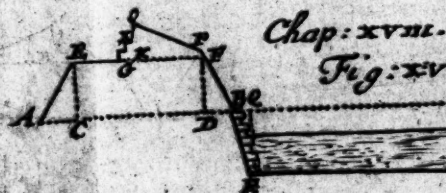
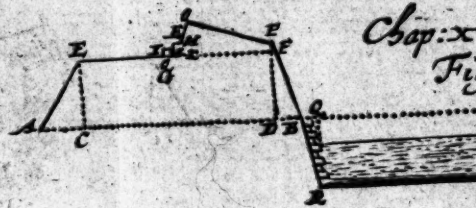
Scale for this plan  10 20 40 60 80 100 Fathoms



CHAP. VI.

M

A Scale for the



A. B. The Base of the
A. C. E. The interior
B. D. F. The exterior
C. E & D. F. The Height
E. G. The top of the
G. I. H. The first face
H. L. M. The second

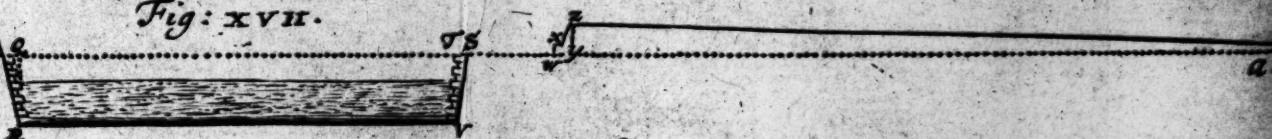
1 2 3 4 5 6 7 8 9 10 Fathoms.

of a Pentagon according to Vauban's
method and of its exterior Works

A

Chap: xviii. Book. iii.

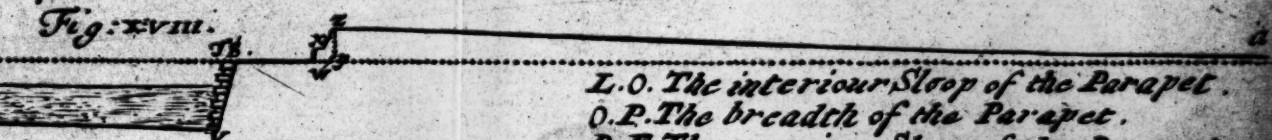
Fig: xvii.



B

Chap: xviii. Book. iii.

Fig: xviii.

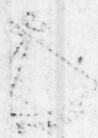


Base of the Rampart.
The interior Sloop of the Rampart.
The exterior Sloop of the Rampart.
The Height of the Rampart.
The top of the Rampart.
The first foot bank.
The second foot bank.

L.O. The interior Sloop of the Parapet.
O.P. The breadth of the Parapet.
P.F. The exterior Sloop of the Parapet.
B.R. The interior Sloop of the Ditch.
S.V. The exterior Sloop of the Ditch.
B.S. The breadth of the Ditch.

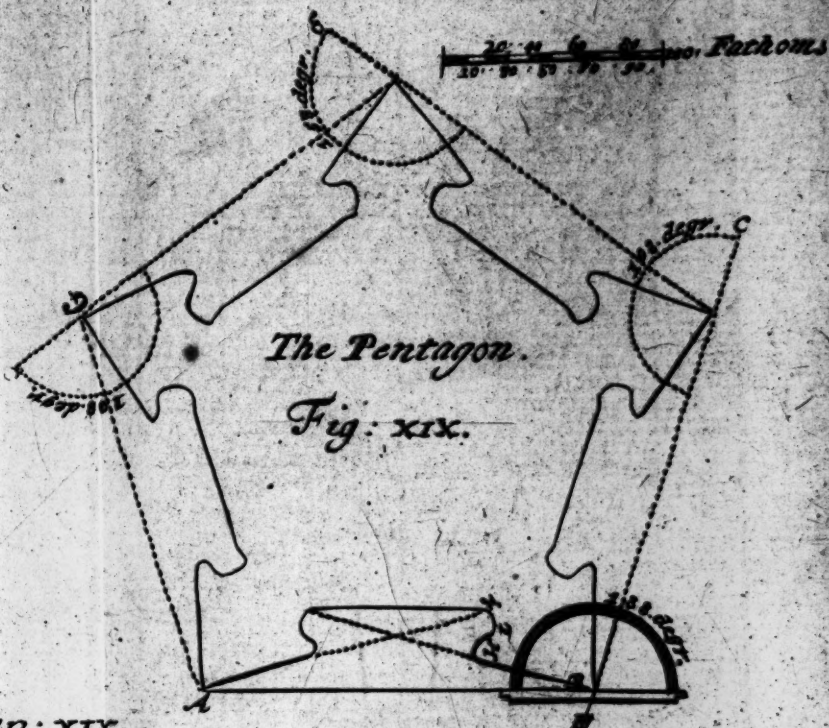
S.W. The cover'd way.
W.a. The Glacis.

N

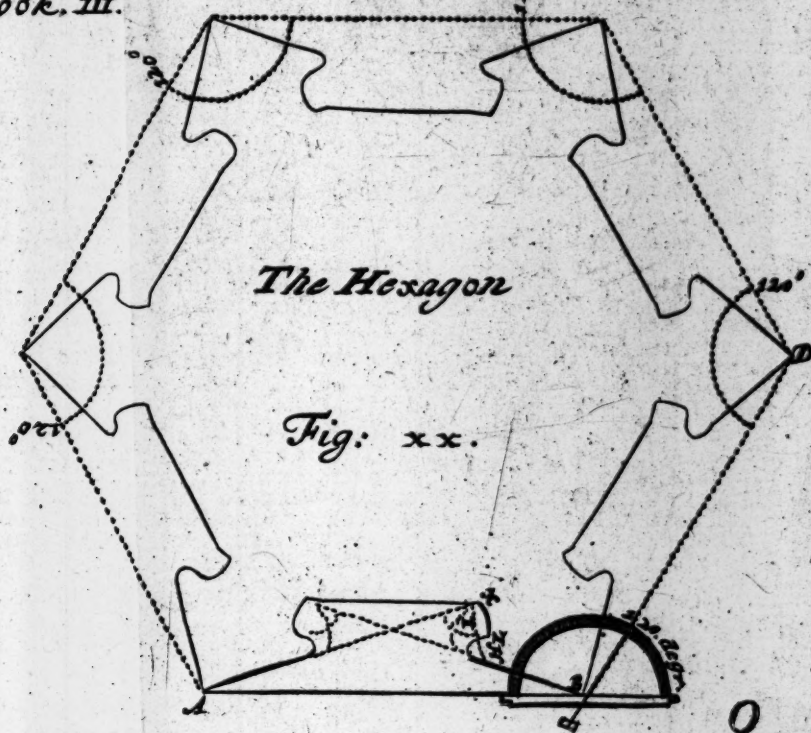


1000
1000





Chap: XIX.
Book, III.



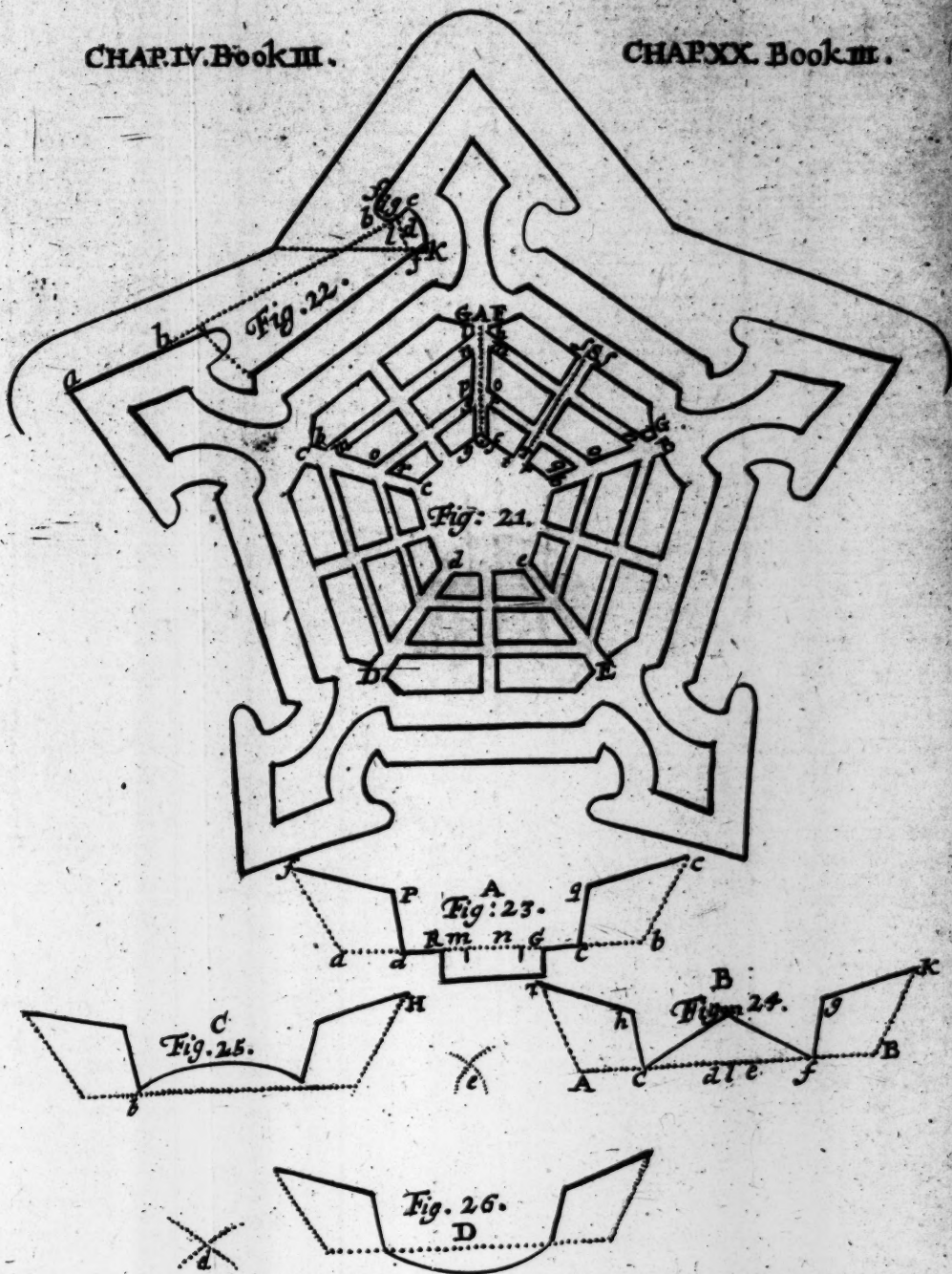
ETARD



10 20 30 40 50 60 70 80 90 100 Fathoms.

CHAP. IV. Book III.

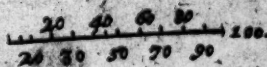
CHAP. XXX. Book III.



These four Draughts or Plains of Courtines belong to
CHAP. V. Book IV.

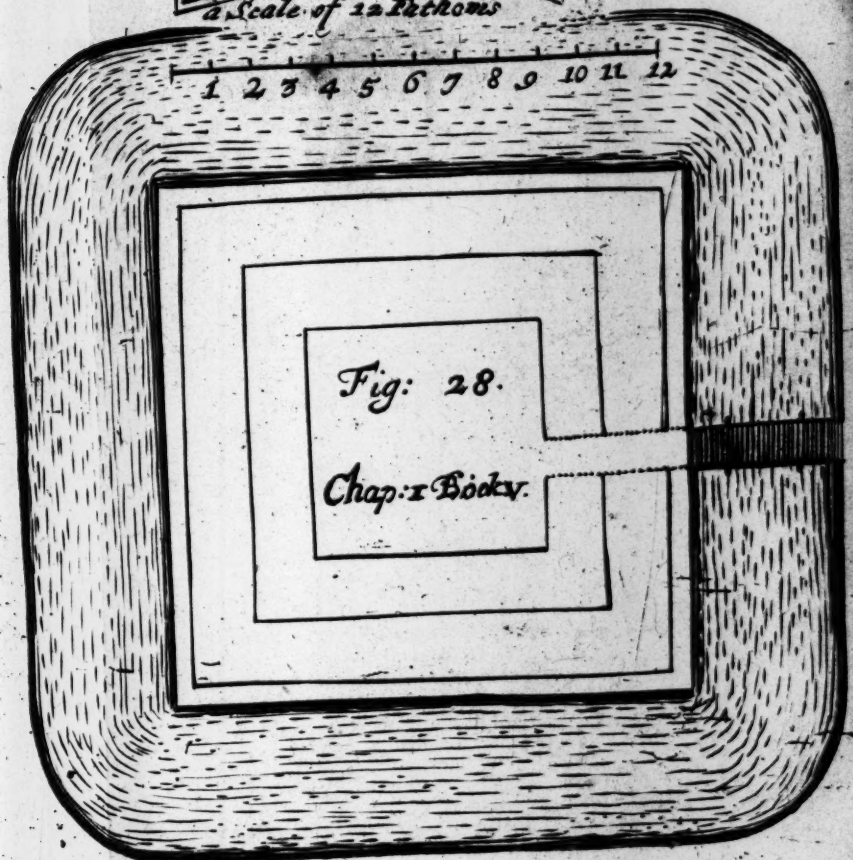
P



A Scale of  Fathoms.

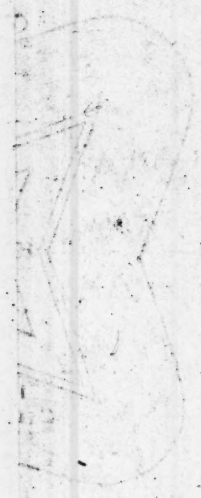


a Scale of 12 Fathoms



1853

CHART



CHART



A Scale of 1 2 3 4 5 6 7 8 9 10 Fathoms

CHAP. II Book V.

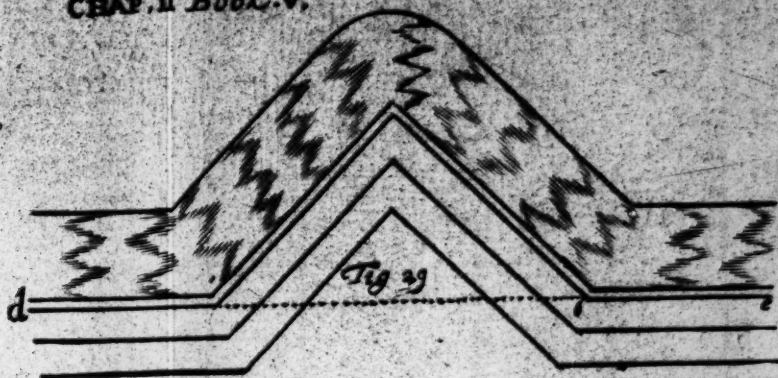
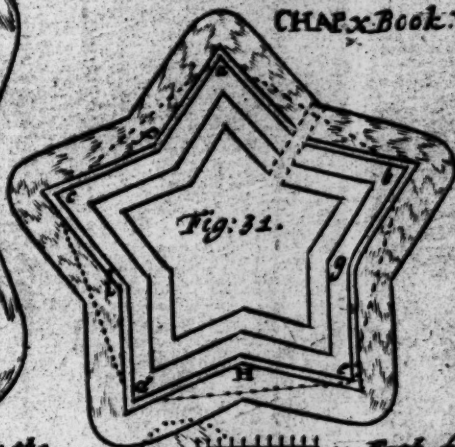


Fig. 30.



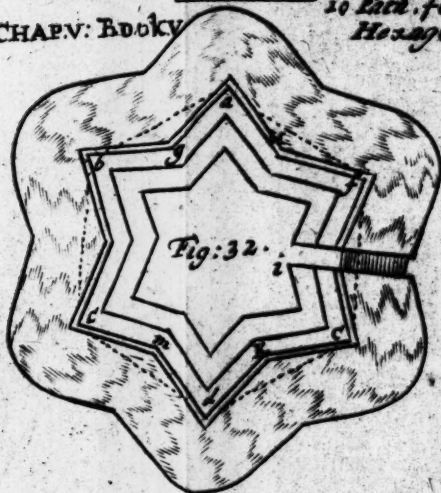
10 Fath. for the Star.
Pentagon.

CHAP. X Book V.



CHAP. V. Book V.

10 Fath. for the
Hexagon.



10 Fath. for
this Triangle.



CHAP. VI Book V.

1800 A
1800



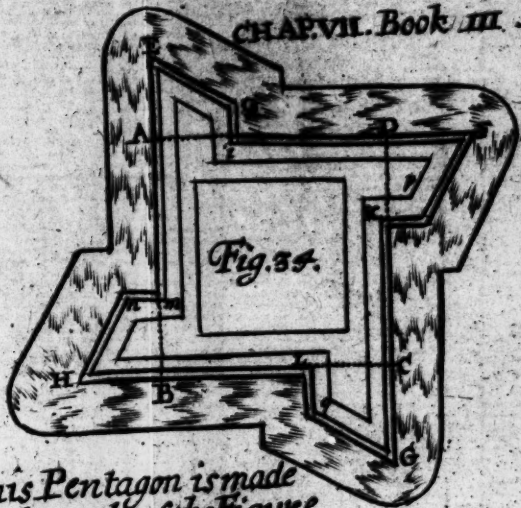
1800 A
1800
1800



A Scale of 10 Fathoms.

A Scale of 10 Fathoms
For 4 Square

CHAP.VII. Book III.



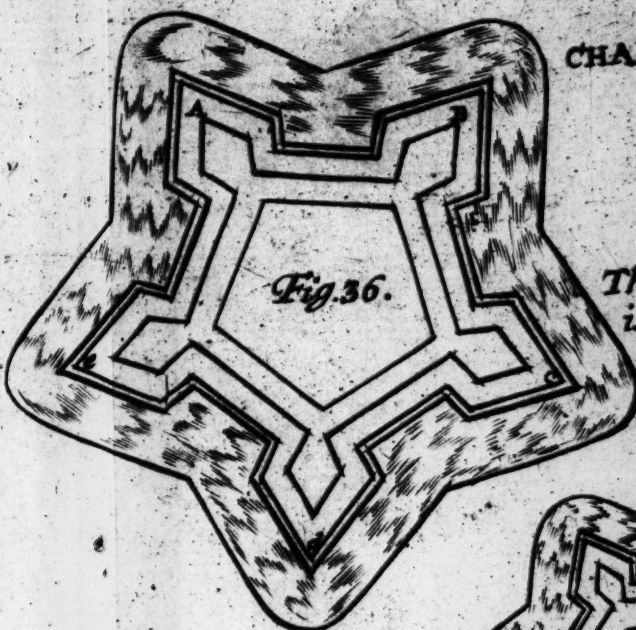
This Pentagon is made
by the Scale of the Figure
above Number 34.

CHAP.VIII. Book IV.

Fig. 35.



CHAP.IX. Book IV.



This demy-Hexagone
is made by the Scale
of Fig. 35.

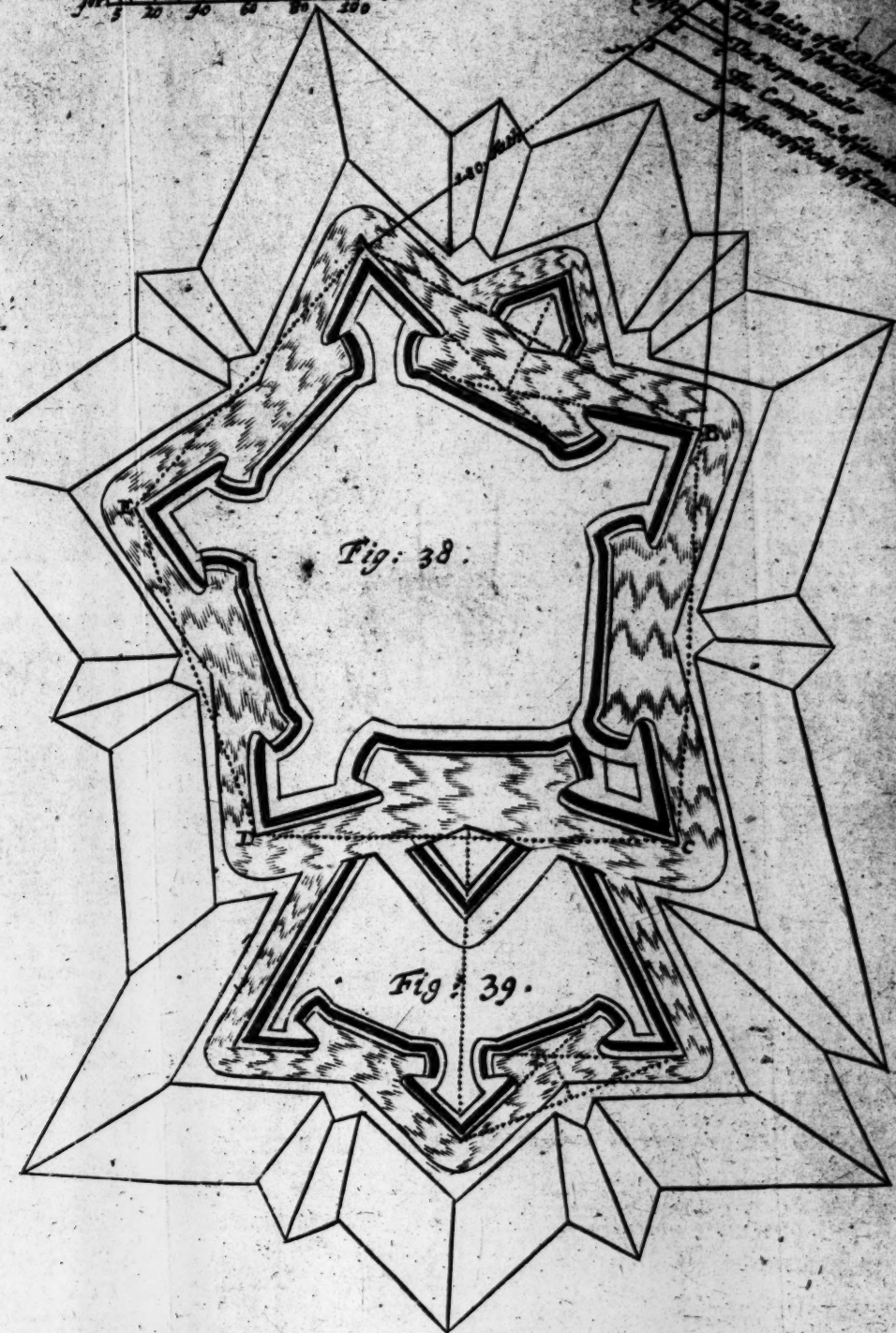


CHAP.X. Book V.



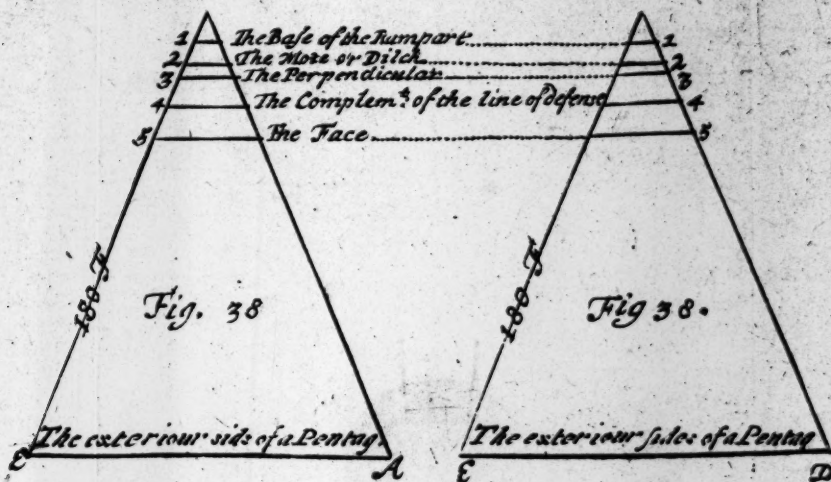
A Scale.
 0 10 20 30 40 50 60 70 80 90 100 Fathoms.

The Axis of the Tower
 The Axis of the Rampart
 The Perpendicular
 The Complement of the Angle of the Rampart
 The Complement of the Angle of the Tower



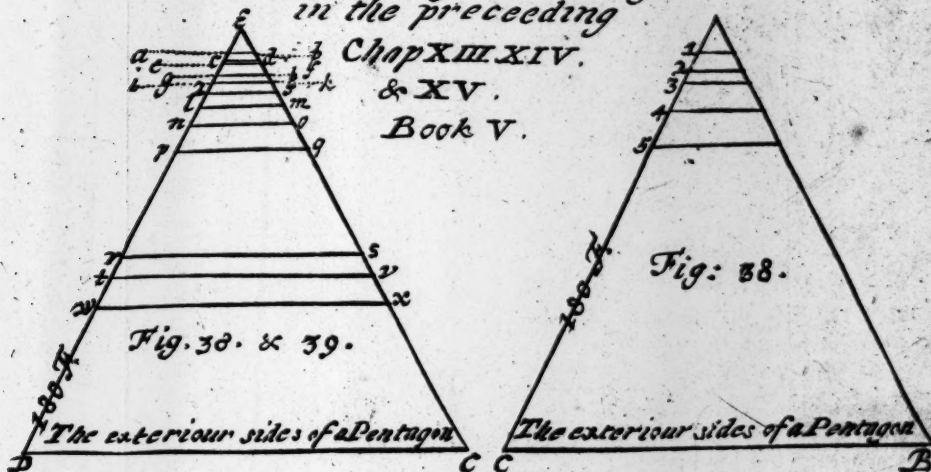


The Scale for these Triangles is in the
preceeding page.



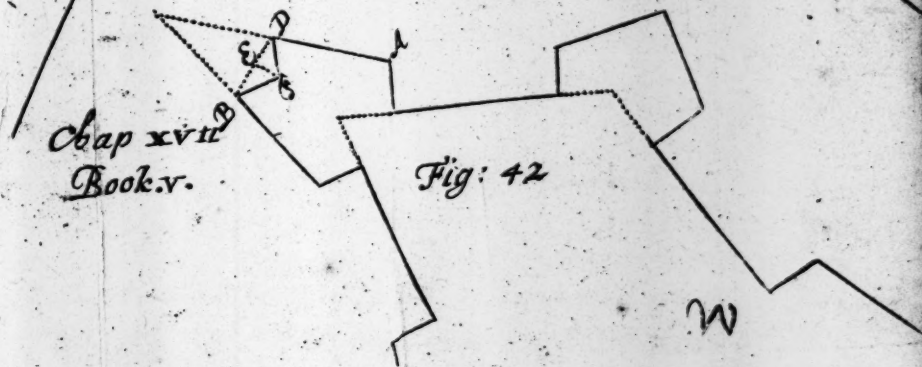
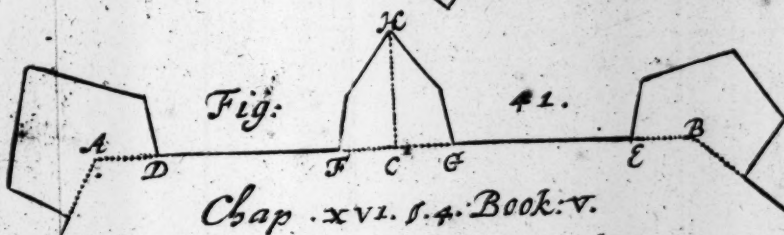
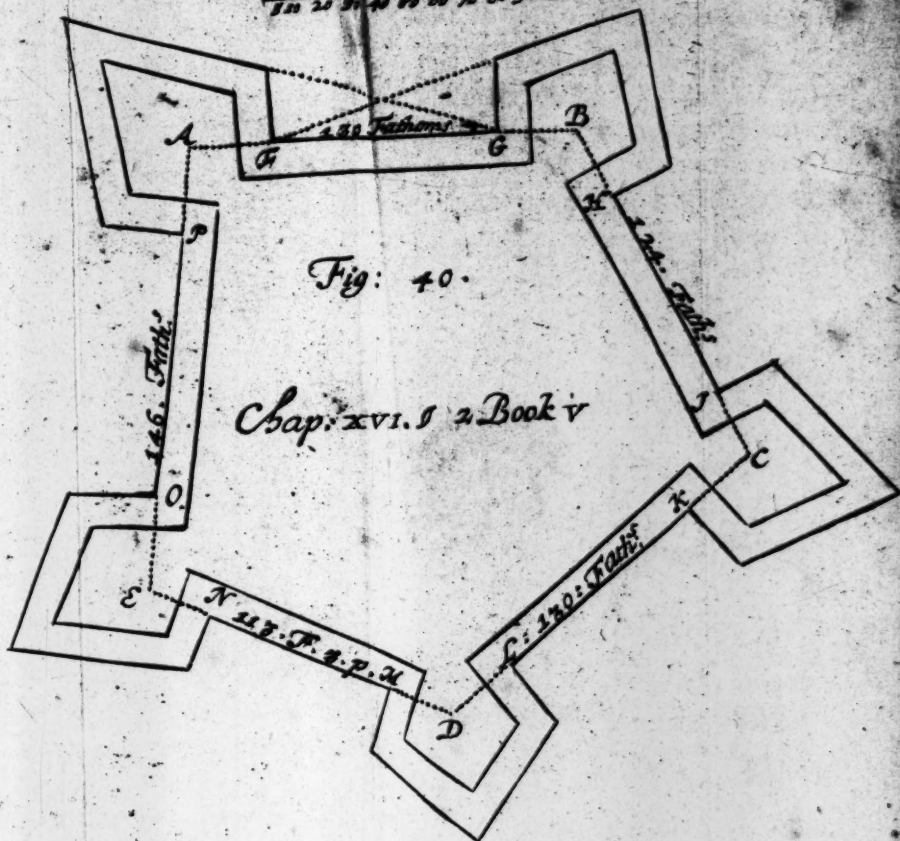
The figure of the Triangles
of the irregular Pentagon
in the preceeding

Chap XIII XIV.
& XV.
Book V.



A Scale for these three Plan's

10 20 30 40 50 60 70 80 90 100 Fathoms.



Chap: xviii Book v.



Chap: xviii Book v.





